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THE EARLY YEARS

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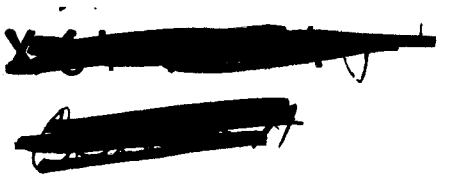
GODDARD SPACE FLIGHT CENTER

Historical Origins and Activities Through December 1962

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



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THE EARLY YEARS.

GODDARD SPACE FLIGHT CENTER

Historical Origins and Activities Through December 1962

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o Goddard Space Flight Center, Greenbelt, Md

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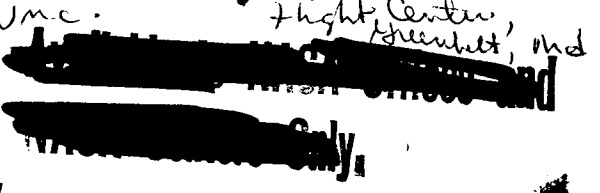

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Mrs. Robert H. Goddard and James E. Webb, Administrator of the National Aeronautics and Space Administration, unveiling sculpture of the late rocket pioneer at the formal dedication of the Goddard Space Flight Center, March 16, 1961.

FOREWORD

In the past five years the Goddard Space Flight Center has magnificently fulfilled its mission to become a symbol of the aims and dedication of my late husband, Robert H. Goddard. As an active division of the National Aeronautics and Space Administration, the Goddard Center has already made many significant contributions to man's knowledge of the upper atmosphere and outer space—the precise goals of my husband's life. Through its televised tracking activities, the name of Goddard has become commonplace in the American home.

Like most scientists, my husband kept a careful and detailed account of his experiments and theories, with occasional summaries and forecasts. It is therefore most appropriate that the Goddard Space Flight Center pause, at intervals, to sum up its activities, evaluate its successes, and plan for even more effective work in the future.

At the dedication of this Center, I remarked that my husband was an extremely happy man, doing what he most wanted to do, with adequate funds in optimum surroundings; and I expressed the hope that many of those who would work at the Goddard Center might be similarly blessed. I feel that this hope is being realized. I also called attention to the opportunities for "the straight thinker and the hard worker," with the wish that the Center would attract such people, and keep them. This, too, has come to pass. With such personnel I have no doubt that this great living memorial will continue to play a vital role in the coming Space Age.

ESTHER C. GODDARD

PREFACE

The purpose of this preliminary historical report is to place between the two covers of a single, readily accessible volume, some of the origins, traditions, and highlights of the early years of the National Aeronautics and Space Administration's Goddard Space Flight Center. It is not intended to replace or to be a substitute for scientific reports and experimental results which are more fully dealt with in other publications. The quick pace of the scientific conquest of space dictates that we not ignore our progress or our accomplishments.

At Goddard, we have attempted to link together, in close intellectual partnership, scientific disciplines heretofore considered relatively dissimilar and self-sufficient. Here, physicist, astronomer, geodesist, mathematician, geologist, engineer, astrophysicist, and others together catalog and analyze the workings of the universe.

The Goddard Space Flight Center is but one of several highly important and specialized segments engaged in scientific exploration of space for which the National Aeronautics and Space Administration was created. From the beginning, Goddard Space Flight Center inherited the great scientific tradition and operational experience from other groups and individuals who already had achieved scientific and professional distinction in the fields of rocket development and space exploration. Thus, the basic roots of the Center's experience and capabilities extend much farther back than does its own history as an organizational entity.

HARRY J. GOETT
Director
Goddard Space Flight Center

INTRODUCTION

The first Goddard Space Flight Center historical report is preliminary in nature but provides a launching pad for a full and accurate historical record tomorrow. Without the contributions of busy history makers, the task of the historian is impossible. Primarily historical documents, a GSFC chronology, and a bibliography are included as appendixes.

This volume is, therefore, a mosaic of what was considered to be reliable information, gleaned from many sources. In preparing this volume, valuable assistance and advice have been received from numerous officials at the National Aeronautics and Space Administration Headquarters—particularly Dr. Eugene M. Emme, NASA Historian, and his associates and Mr. T. E. Jenkins, NASA Management Reports Director, formerly of the Goddard Space Flight Center—and from the entire Center staff. Without the considerate support from virtually every element of the agency, the preparation of this document would have been an almost impossible task. Any comments, suggestions, or corrections of facts are sincerely invited.

ALFRED ROSENTHAL
Historian
Goddard Space Flight Center

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Part I

HISTORICAL ORIGINS OF THE GODDARD SPACE FLIGHT CENTER

No single thing abides; but all things flow.
Fragment to fragment clings – – the things thus grow
Until we know them and name them. By degrees
They melt, and are no more the things we know.

—*Hallock*

Dr. Goddard at work on his rocket in his shop at Roswell, New Mexico, October 1935.

Chapter 1

FROM ROBERT H. GODDARD TO THE INTERNATIONAL GEOPHYSICAL YEAR

The historical traditions of the Goddard Space Flight Center have antecedents in a period long before America's awakening to the Space Age. Named in honor of Dr. Robert H. Goddard, the NASA Center continues in the scientific tradition of this New England scientist, who has been recognized as the "Father of American Rocketry" and as one of the pioneers in the theoretical exploration of space.

Dr. Goddard was one of those rare combinations occasionally appearing in the history of science and technology; he was a theoretical scientist and a practical and exacting engineer, but he was also a dreamer who was considerably ahead of his time. His particular dream was the conquest of the upper atmosphere and ultimately the void of space through the use of rocket propulsion. To the fulfillment of this dream, Dr. Goddard devoted his talents, his energies, and his life. He had the drive and single-mindedness also found today among those who are probing the innermost secrets of space.

THE LIFE OF DR. GODDARD*

Robert Hutchings Goddard was born in Worcester, Massachusetts, on October 5, 1882. Childhood illnesses prevented the young boy from expressing his energy in the usual aimless manner. As a consequence, he developed his imagination and read voraciously. He was greatly influenced when he read H. G. Wells' *War of the Worlds*. An acquaintance with the works of Jules Verne also stimulated his imagination. Dr. Goddard is known to have read annually and ultimately to have rewritten Verne's *From the Earth to the Moon* to include a rocket launch instead of a cannon.†

A germ of his later work might be seen in his effort in the spring of 1898 to construct a hydrogen filled balloon made of thin aluminum. Although it was too heavy to fly, Goddard was not discouraged, and he turned his attention to such other things as "how birds fly" (which also interested two young brothers named Wright, in Ohio) and the marvels of electricity. This was the situation when, on the afternoon of October 19, 1899, he found himself high in a cherry tree, assigned the duty of clipping its dead limbs. It was, he said, "one of those quiet, colorful afternoons of sheer beauty which we have in October in New England . . . as I looked toward the fields to the east, I imagined how wonderful it would be to make some device which had even the *possibility* of ascending to Mars, and how it would look on a small scale if sent up from the meadow at my feet . . . I was a different boy when I descended the ladder. Life now had a purpose for me." ‡

The young Robert Goddard began to construct models of his own design and devoted himself, in high school, to the study of physics and mathematics. By the time he graduated, he had, he said, "a set of models which would not work and a number of suggestions which, from the physics I had learned, I knew were

*For further references see the attached bibliography, p. 6.

† Hagemann, E. R., "Goddard and His Early Rockets: 1882–1930," *Journal of the Astronautical Sciences*, Vol. 8, No. 2, Summer 1961, p. 51–52; Thomas, S., "Robert H. Goddard," *Men of Space*, 4 vols., Chilton Co., Philadelphia, 1960, Vol. 1, p. 23. For a fuller account see the new biography of Goddard, "This High Man," by M. Lehman, to be published in the fall of 1963.

‡ Goddard, R. H., "An Autobiography," *Astronautics*, Vol. 4, No. 4, Part 1 of 2 parts, April 1959, p. 27.

erroneous." He gathered up all his models and his carefully catalogued notes and burned them.*

"But the dream would not go down," wrote Dr. Goddard in later years, "and inside of two months I once again caught myself making notes of further suggestions, for even though I reasoned with myself that the thing was impossible, there was something inside me which simply would not stop working." As early as 1909, Goddard conceived the multiple-stage rocket, the general theory of hydrogen and oxygen propulsion, and the use of planes for guidance.*

By this time, Goddard had graduated from Worcester Polytechnic Institute with a B.S., holding high honors in physics and mathematics. All through college the young scientist had been absorbed by his obsession with propulsion. Near the end of his senior year, he filled the basement of the WPI Physics Building with smoke, the result of a static test of a small rocket.†

The years between graduation from WPI and 1919 were full and arduous ones for Goddard. He stayed on at the Worcester Tech as an instructor in physics while doing graduate work at Clark University, where he received his A.M. in 1910 and his Ph. D. in physics in 1911. He then spent a year at Clark as an honorary fellow in physics, where he worked on various rocketry methods. In 1912 he went to Princeton as a research fellow and worked on electrical theory (the subject of his Ph. D. dissertation) during the day and on rocket propulsion theory during the evenings. Illness during 1913–1914 prevented him from teaching but did not hinder his speculations on rocketry. In fact, during his convalescence Dr. Goddard laid the foundations for two patents, received in July 1914, which developed his idea of a multi-stage rocket and liquid propellants.

In the autumn of 1914, Dr. Goddard returned to Clark University as an instructor and began his basic work on rocketry, which led to the now famous 1919 Smithsonian publication. It was during this period that he proved his theory, by static laboratory test, that a rocket would perform in a vacuum and was therefore capable of operating in space. By the middle of 1916, he had reached the limit of what he could accomplish on his own funds. He wrote up his experiments, entitled the manuscript "A Method of Reaching Extreme Altitudes," and sent it to three organizations which he thought might be interested enough to aid him financially. The only encouraging reply he received was from the Smithsonian Institution, which asked for further details. This was in December 1916. After receiving the Smithsonian's commendation for his work, Dr. Goddard requested $5000 to continue his experiments. It was granted, and the next letter from Washington contained an advance of $1000.‡

Thus began, in January 1917, the years of experimentation which Dr. Goddard continued unceasingly for the remainder of his life. When the United States entered World War I in 1917, he volunteered to direct his rocket research toward ends which might prove useful to the military. This work led to the development of a prototype of the World War II "bazooka"; however, the war ended five days after he demonstrated it. During World War II, Dr. Goddard's invention was "dusted off" by his colleague, Dr. Clarence N. Hickman, and was perfected to provide the American soldier with the first effective hand weapon against the tank.§

After returning to Clark in 1919, Dr. Goddard persuaded the Smithsonian to publish his revised "Method of Reaching Extreme Altitudes"—a rather dry and factual report of his experiments over the preceding several years, designed to show the Smithsonian where its money was going. It was released on January 11, 1920, as Smithsonian Miscellaneous Publication Number 2540. In this publication, Dr. Goddard was indiscreet enough to suggest the possibility that someday a rocket such as the

*Goddard, p. 27.

† Emme, E. M., "Yesterday's Dream . . . Today's Reality; A Biographical Sketch of the American Rocket Pioneer, Dr. Robert H. Goddard," *The Airpower Historian*, October 1960, p. 218.

‡ Hagemann, pp. 53–54: Pendray, G. E., "Pioneer Rocket Development in the United States," *Technology and Culture*, Vol. 4, No. 4, Fall 1963.

§ Lehman, M., "The Strange Story of Dr. Goddard," *Reader's Digest*, November 1955, p. 149.

one he was designing might be used to hit the moon. The newspapers picked up the story and portrayed him as a crackpot. This adverse publicity had a deep and lasting effect on Dr. Goddard. From that day forward, he rarely spoke of anything which might pertain to space flight, and he avoided publicity for himself and his work. In private, however, he continued to speculate on the possibilities of the rocket in space, on methods of navigating in space, and on the potentialities of a solar-powered engine. All of this he kept locked away in a cabinet in a folder marked "Formulae for Silvering Mirrors."*

In the early 1920's Dr. Goddard began his pioneering experimentation with liquid-fuel propulsion. He had considered the idea of a hydrogen and oxygen fuel supply as early as 1909. After several experiments he discovered that oxygen and gasoline made the most practical fuel, and the first static test of liquid-fuel propulsion was made on November 1, 1923. After overcoming numerous problems with the apparatus, the fuel pumps in particular, he was ready to try again. On March 16, 1926, Professor Goddard, his wife Esther, and two assistants drove to "Aunt Effie" Ward's farm near Auburn, Massachusetts, and prepared his rocket for launch. Ignition was accomplished by a blowtorch attached to a pole. The rocket rose from the ground, traveled a distance of 184 feet, reached a speed of 60 miles per hour, and stayed in the air for 2½ seconds. It was the first liquid-fuel rocket flight in the world, an event comparable to Kitty Hawk in its significance. Not a word reached a newspaper.†

Dr. Goddard continued his experiments at Auburn until July 17, 1929, when he launched a scientific payload of a barometer, a thermometer, and a camera. On that date a successful launch resulted in someone's mistaking the rocket for an airplane in flames, which caused the State Fire Marshal to forbid Goddard to conduct any more tests in Massachusetts. The Smithsonian thereafter succeeded in persuading the Army to allow him to launch his rockets on Federal property at Camp Devens; but as a precaution against fires he could experiment only after a rain or a snowfall. However, the "moon-rocket man" publicity from this affair brought Goddard an unexpected windfall. Up to this time he had been relying on the relatively small but steady grants from the Smithsonian for the necessary financial assistance. Charles A. Lindbergh, who was at the height of his popularity, read the unfavorable press accounts of Goddard's work. He visited Dr. Goddard and was impressed with him. Lindbergh took Goddard's cause to Daniel and Harry Guggenheim. Subsequently the Daniel and Florence Guggenheim Foundation began to supply him with money for his experiments. Between 1929 and 1941, Dr. Goddard received over $150,000 from this source.‡

The first Guggenheim grant of $25,000 enabled Dr. Goddard to leave Massachusetts for a more suitable testing ground. He moved his work to Roswell, New Mexico, which was to be his headquarters for the remaining fifteen years of his life. All through the 1930's Dr. Goddard and his small staff worked at Roswell, improving his rockets and their components. While there, he devised and patented a gyroscopic control for rockets and an ingenious system for cooling the combustion chamber, called "curtain cooling," in which the fuel of the rocket acted as the cooling agent. "There was never so much invention with so little manpower," remarked one of Dr. Goddard's mechanics.§

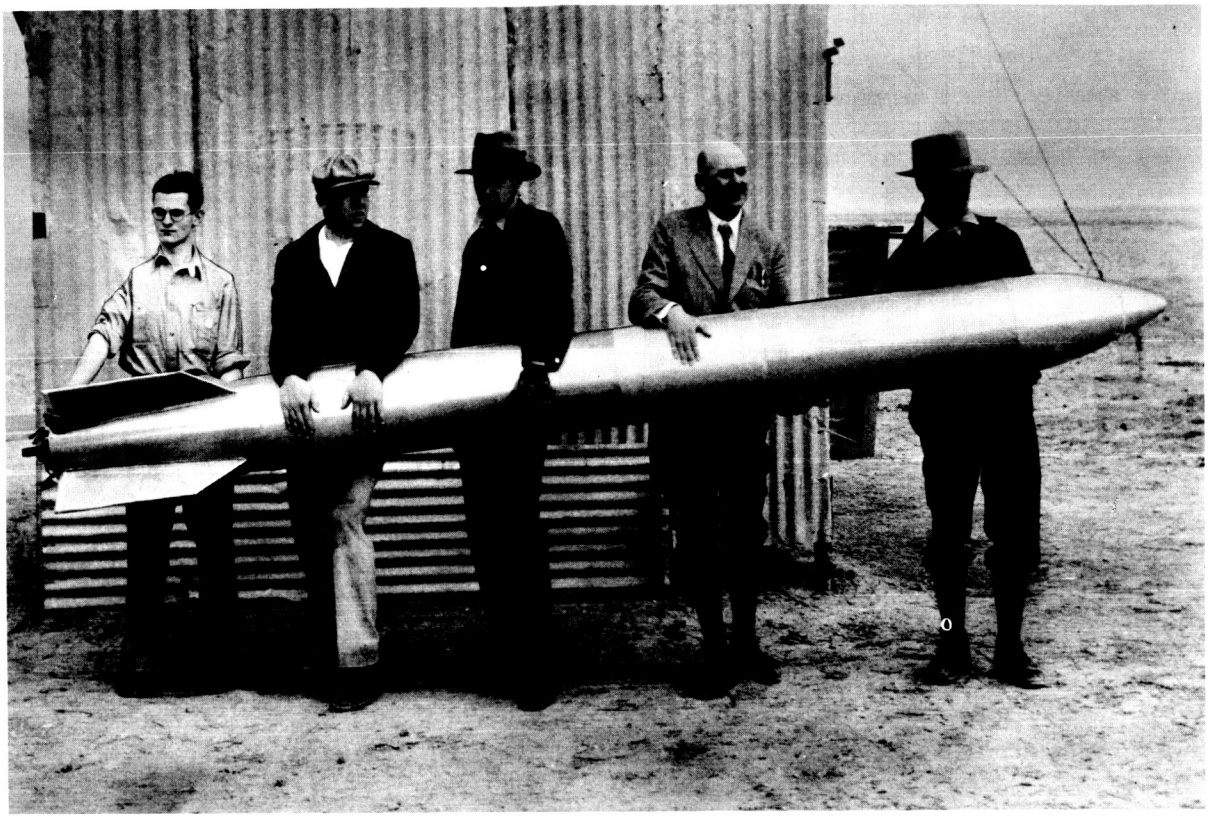
When war broke out in Europe in 1939, Dr. Goddard visited the U.S. War Department and tried to interest the military in his work, but nothing tangible resulted. When the United States became involved in 1941, the Navy and the Army Air Corps asked him to work for them, not to develop his rocket as an offensive or defensive missile but merely to develop a jet-assist takeoff (JATO) device for launching airplanes from short runways or aircraft carriers. Dr. Goddard's repeated efforts to convince the American military of the wartime potential of the rocket were to no avail. So it happened that JATO and the revived 1918 "bazooka"

*Lehman, p. 150; Hagemann, pp. 54–56.

† Hagemann, p. 57; Emme, p. 219.

‡ Emme, pp. 219–220.

§ Goddard, R. H., "Rocket Development; Liquid-Fuel Rocket Research, 1929–41," (New York: Prentice-Hall, 1948).



Dr. Goddard and colleagues holding the rocket used in the flight of April 19, 1932. They are, from left to right, L. Mansur, A. Kisk, C. Mansur, Dr. R. H. Goddard, and N. L. Jungquist.

were the major contributions which this genius made to the American war effort.*

The Germans, however, had not neglected their rocket technicians since 1931, as had the Americans. By 1944, German V–2 ballistic rockets began to fall on Britain. The Allies were startled at the progress of German rocketry. When details of the V–2 reached Annapolis, where Dr. Goddard was working in the Navy's research laboratories, he noted the similarity between the German missile and his own liquid-fuel rocket. Although the 5½-ton V–2 was much larger than anything that Dr. Goddard had ever constructed, the two rockets were almost identical in basic design. Out of this similarity arose a controversy over the extent to which the Germans had worked from Goddard's designs.†

In Baltimore, in 1945, Dr. Goddard was operated on for throat cancer. His lungs, weakened from an earlier attack of tuberculosis, gave out and the American rocket pioneer died on August 10, 1945. His passing went practically unnoticed except among his faithful small group of family and friends.‡

THE GODDARD LEGACY

Robert Hutchings Goddard was as responsible for the dawning of the Space Age as were the Wrights for the beginning of the Air Age. Yet his work attracted little serious attention during his lifetime. When the United States began to prepare for the conquest of space in the 1950's, American rocket scientists began to recognize the enormity of the debt which their science owed to the New England professor. They discovered that it was virtually impossible to construct a rocket or launch a satellite without acknowledging the work of Dr. Goddard. This great legacy was covered by more

*Emme, p. 220; Lehman, p. 152.

† Emme, p. 220, Lehman, pp. 147, 152.

‡ Lehman, p. 152.

Dr. Robert H. Goddard and colleagues at Roswell, New Mexico. Successful test of May 19, 1937. Dr. Goddard is holding the cap and pilot parachute, parts of the successful operation.

than 200 patents, many of which were issued after his death.

Belated honors have begun to pour upon the name of Robert Goddard in recent years.* On September 16, 1959, the Congress of the United States authorized the issuance of a gold medal in his honor. The Smithsonian Institution, long familiar with his work, awarded him its coveted Langley Medal, in honor of his discoveries in rocketry, on June 28, 1960.

On May 1, 1959, the National Aeronautics and Space Administration named its new Space Flight Center at Greenbelt, Maryland, the Goddard Space Flight Center.† It is hardly a coincidence or accident that his name has been chosen to inspire the work being done by the Goddard staff of scientists and engineers engaged in the exploration of space. It is perhaps one of the most fitting of the many belated honors which have come to the name of Goddard, because it established a Center which is continuing the fulfillment of the dream the young Goddard conceived at the turn of the century.

The essense of his philosophy, as he expressed in his high school oration, serves as the motto of the Goddard Space Flight Center:

> *"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."*

Dr. Goddard at work on his rocket in his shop at Roswell, New Mexico, October 1935.

GODDARD'S HISTORIC FIRSTS

Robert H. Goddard's basic contributions to rocketry and space flight make up a lengthy list. As such, it is an eloquent testimonial to his lifetime of work in establishing and demonstrating the fundamental principles of rocket propulsion.

First explored mathematically the practicality of using rocket propulsion to reach high altitudes and to shoot to the moon (1912)

First received a U.S. patent on the idea of a multi-stage rocket (1914)

First proved, by actual static test, that a rocket will work in a vacuum, that it needs no air to push against (1915–16)

* See end of this chapter for a list of these honors.

† The Center was formally dedicated as the Goddard Space Flight Center on March 16, 1961.

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First developed suitable pumps for rocket fuels (1923)

First developed and fired a liquid-fuel rocket (March 16, 1926)

First shot a scientific payload (a barometer, a thermometer, and a camera) in a rocket flight (1929)

First used vanes in the rocket motor blast for guidance (1932)

First developed gyro control apparatus for rocket flight (1932)

First fired a liquid-fuel rocket faster than the speed of sound (1935)

First launched successfully a rocket with a motor pivoted in gimbals controlled by a gyro mechanism (1937)

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A full-scale biography of Dr. Goddard will appear in the fall of 1963. *This High Man*, by Milton Lehman, has been written largely from Dr. Goddard's papers and probably will prove to be definitive. Mrs. Goddard is also editing, for publication by the McGraw–Hill Co., her husband's notebooks, correspondence, and papers prior to their desposition in the Library of Congress. The following is a partial bibliography of works which are either by or about Dr. Goddard or which touch on the pioneer history of rocketry:

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ROBERT H. GODDARD EXHIBITS AND MEMORIALS

Exhibits

National Air Museum, Smithsonian Institution, Washington, D.C.—Exhibit of the four complete extant Goddard rockets, made in 1926, 1935, 1938, and 1941; also some rocket parts, an oil portrait of Dr. Goddard, and a few personal memorabilia. Probably the best Goddard exhibit in the U.S.

Institute of the Aerospace Sciences, New York City—Goddard collection of early rocket literature, one of the best in the U.S. The Institute had, from 1950 to 1959, an exhibit of numerous devices and parts developed and used by Dr. Goddard from 1918–1945, which is on long-term loan to the Roswell Museum, Roswell, New Mexico.

Roswell Museum, Roswell, New Mexico—Largest exhibit of parts of Goddard rockets, housed in the Goddard Wing of museum (dedicated April 25, 1959), including piping, drawings, murals of life-size photographs of four Smithsonian rockets, etc.

On the grounds of the museum is the launching tower used by Dr. Goddard, with a copy of the 1940 rocket in it. His observation tower is also on the grounds.

Clark University, Physics Department, Worcester, Mass.—Small, but good collection of Clark-owned rocket parts, with additional items given by Mrs. Goddard. Also life-size photos, used as murals, of the four Smithsonian-held rockets, and bronze tablet at entrance to Physics Building, a gift of the Class of 1959.

Worcester Polytechnic Institute, Worcester, Mass.—Small collection of solid-propellant rockets, some of which were developed in WPI building and grounds. Also set of four murals of life-size Smithsonian rockets.

Memorials and Awards

Robert H. Goddard Professorships, at Guggenheim Jet Propulsion Centers, at Princeton University and the California Institute of Technology, established by The Daniel and Florence Guggenheim Foundation.

Goddard Award, given by the American Rocket Society annually to the missile worker selected by its Directors as having made the greatest contribution to rocket development during the year; the oldest award in the missile field.

Goddard Athletic Field, White Sands Proving Ground, New Mexico.

Goddard Oval, at Allegany Ballistics Laboratory, Cumberland, Maryland.

Goddard House, guest house for visiting dignitaries at Redstone Arsenal, Huntsville, Alabama.

Goddard Power Plant, multimillion dollar plant at the Naval Proving Ground, Indian Head, Maryland, in memory of Dr. Goddard's work there in 1920–1922.

Cathedral of the Pines, Rindge, N.H.—Piece of petrified wood, used by Dr. Goddard as paper weight in New Mexico, imbedded in lectern. Gift of Mrs. Goddard, who is a trustee of the Cathedral.

WPI 1908-Goddard Memorial Fund—Established by the Class of 1908 of Worcester Polytechnic Institute in June 1958; income to be used for prize or scholarship.

Hill Transportation Award, of the Institute of the Aerospace Sciences.—Carrying $5000 and citation, accepted for Dr. Goddard by Mrs. Goddard at the annual dinner of IAS, January 1959.

Golden Replica of 1926 Goddard Rocket—Accepted for Dr. Goddard by Mrs. Goddard at the Missile Industry Conference at Washington, D.C., June 1958. Now on view at the Goddard Space Flight Center, Greenbelt, Md.

Goddard Trophy and *Goddard Scholarship*—Given annually at the Goddard Memorial Dinner of the National Missile Industry Conference at Washington, D.C., sponsored by the National Rocket Club.

Air Force Academy Goddard Award, Colorado—Established by the American Ordnance Association, to the cadet with the highest standing in mathematics in each graduating class.

Langley Medal—Dr. Goddard was the ninth recipient of this coveted medal from the Regents of the Smithsonian Institution at Washington, D.C. Presented to Mrs. Goddard at Washington, June 28, 1960.

American Rocket Society Goddard Memorial—Granite marker at site of the first flight of a liquid-propellant rocket, March 16, 1926, at Auburn, Mass., with a granite tablet beside road nearby, explaining significance of the marker. Dedicated July 13, 1960.

Congressional Medal—Presented posthumously to Dr. Goddard on March 16, 1961, at the dedication of the Goddard Space Flight Center, Greenbelt, Md.

NASA Goddard Space Flight Center—Complex of new buildings of the National Aeronautics and Space Administration at Greenbelt, Md., dedicated March 16, 1961.

Goddard Institute for Space Studies, extension in New York City of the Goddard Space Flight Center, established Jan. 1961.

Goddard Alumni Award—Established by the alumni of Worcester Polytechnic Institute, to be awarded annually to an outstanding alumnus, June 1961.

Robert H. Goddard Squadron—Air Force Association, Vandenberg Air Force Base, California, 1961.

Robert H. Goddard Industrial Center, Worcester, Mass.—Dedicated June 19, 1961.

Goddard Science Symposium of the American Astronautical Society—Annually on March 16, at Washington, D.C.

Robert H. Goddard Historical Essay Competition of the National Rocket Club—Prize of $200 and trophy awarded annually for the best essay on the historical development of rocketry and astronautics, March 1962.

Goddard Prize of the Massachusetts Delta Chapter, Sigma Alpha Epsilon, at Worcester Polytechnic Institute—Given semiannually for improvement in scholarship, Fall 1961.

Goddard Avenue—The main street at Malmstrom Air Force Base, Montana, dedicated in July 1962.

Robert H. Goddard Boulevard—The Valley Forge Space Technology Center of the General Electric Company, Valley Forge, Pa., dedicated October 12, 1962.

Robert H. Goddard Achievement Award—In Civil Air Patrol Cadet Aerospace Education and Training Program, National Headquarters, Ellington Air Force Base, Texas.

Robert H. Goddard Memorial—Tower and rocket at Fort Devens, Mass., at the site of the Goddard testing tower, 1929–1930. Dedicated in May 1963.

Robert H. Goddard Junior High School 202, 90–15 Sutter Ave., Ozone Park, N.Y. (in Queens, near International Airport)—Opens Fall 1963.

Robert H. Goddard Senior High School, Roswell, New Mexico—Under construction, 1963.

Chapter 2

FROM PROJECT VANGUARD TO THE GODDARD SPACE FLIGHT CENTER

After World War II, interest in rocket technology gradually developed in the United States. This was partially due to a growing awareness of Dr. Goddard's experiments, but more important was the impact which the German V–2 rocket had made on American military and scientific circles during the war. At the end of the war, a number of these rockets fell into U.S. hands and were brought to the United States, where their potential was quickly realized. Scientists recognized them to be of great value in high-altitude research, while military considerations aroused the interest of the Army.

THE UNITED STATES V–2 PROGRAM

In January 1946, the U.S. Army announced that a firing program for these V–2 rockets would begin later that year at White Sands, New Mexico. Governmental agencies and several universities were invited to consider using the V–2's for high-altitude research and experimentation. From this developed the informal "V–2 Upper Atmospheric Research Panel." Some of the results of the U.S. V–2 program were obtained by the Naval Research Laboratory's upper atmospheric research group, which consisted largely of the same people who were to transfer to NASA a decade or so later—Dr. Homer E. Newell, Milton W. Rosen, Dr. John W. Townsend, Leopold Winkler, Daniel G. Mazur, and others.*

The first V–2 to be used in the sounding rocket research program was launched in June 1946. In the next six years, over 60 were launched. They pioneered atmospheric soundings to an altitude of about 100 miles. An entire series of measurements of high-energy particle radiation, found at high altitudes but absorbed at lower levels, was made. The work was scientifically promising, but inevitably the supply of German V–2 rockets became depleted. Thus it became necessary to develop an American source for the same or a similar type of sounding rocket.†

The first of these rockets was the Aerobee, designed by the Applied Physics Laboratory of Johns Hopkins University. It was capable of carrying a small payload to an altitude of about 80 miles. In 1947, the Naval Research Laboratory, in Washington, D.C., proposed the construction of a rocket which would replace the V–2 in the American sounding rocket program. This missile, at first called Neptune but later identified as Viking, was smaller than the V–2 but more powerful. It could lift a larger payload to a height of about 150 miles with a high order of stability. In the six years between 1949 and 1955, twelve of these rockets were launched, carrying payloads of more than 800 pounds as high as 158 miles. None attained the hoped-for altitude but new records were established and valuable scientific information was gained.‡

EARLY U.S. SATELLITE PROPOSALS

Although the main emphasis in these years was on the development of an improved rocket-powered vehicle, a germinal program was initiated in the field of earth satellites. The U.S. Navy's Bureau of Aeronautics was one of the first government organizations to initiate a satellite study program. In October 1945, a committee of the Bureau of Aeronautics rec-

*Statement of Mr. T. E. Jenkins, formerly Administrative Officer of the Beltsville Space Center, July 15, 1963.

†Hagen, J. P., "The Viking and the Vanguard," *Technology and Culture*, Vol. 4, No. 4, Fall 1963, p. 42.

‡Hagen, p. 43.

ommended that an earth satellite program be undertaken for scientific purposes. The Aerojet Corporation and the California Institute of Technology were given the task of determining whether such a project was technically feasible using the single-stage rocket vehicle which the Navy had proposed.*

In March 1946, the Navy took its proposal to the Army Air Force for the purpose of suggesting a joint satellite program. Although the first effort at such a program appeared promising, the Air Force soon informed the Navy that they could not cooperate. In the meantime, the Air Force had gone to Project RAND (later to become the RAND Corporation) and requested that they begin a satellite feasibility study. RAND drew up a proposal for the Air Force entitled "Preliminary Design of an Experimental World-Circling Spaceship." The RAND proposal ruled out the satellite as a military weapon because no rocket could be constructed which could lift the heavy A–bomb into orbit and no explosive force short of an atomic one would inflict enough damage to warrant the expense of putting it into orbit. The problem was not one of capability (it was assumed that the U.S. could launch a 500-pound satellite by 1951) but rather one of devising a useful function for the satellite to perform once it was in orbit. Because a satellite was not a potential weapon, there were no funds available for its development.†

The RAND-Air Force proposal, like its Navy counterpart, urged the early adoption of a satellite program for scientific purposes. They argued for its capabilities in the fields of meteorology, communications, and astronomy. In October 1946, RAND issued an additional study entitled "The Time Factor in The Satellite Program," in which they emphasized the propaganda and political factors which would result from a U.S. satellite launch. Even this was insufficient to overcome the factor that the satellite was not a potential weapon.

When the Department of Defense (DOD) was created in 1947, none of the three military services was authorized to continue development of a rocket with satellite capability. The Air Force discontinued its satellite studies in mid-1947 but did resume them in 1949. By that time, the Navy had discontinued its studies because of lack of funds. Early in 1948, DOD reviewed the existing satellite proposals but again concluded that "neither the Navy nor the USAF has as yet established either a military or a scientific utility commensurate with the presently expected cost of a satellite vehicle." The work was so neglected at DOD that, in November 1954, the Secretary of Defense could remark that he knew of no American satellite program.‡

The RAND Corporation proved to be prophetic in its prediction of the great psychological–propaganda impact of a satellite launch. They had emphasized, as early as 1946, that a satellite would be an "instrument of political strategy." When the Soviet Union launched Sputnik I in October 1957, it had exactly the impact that RAND had said it would have—only in reverse. It was the United States which did the soul-seeking and suffered the disdain of world opinion. It was only after this 1957 propaganda defeat that the U.S. Government fully understood the great significance of these early satellite studies.§ Yet, at the time of the first Sputniks, there actually was a satellite program in the United States.

THE INTERNATIONAL GEOPHYSICAL YEAR

While rocket development and satellite proposals were proceeding within the military, an important boost was given to the scientific application of rocket technology. By 1951, the American Rocket Society had grown to a point where its voice could be heard. In the winter of that year, Commander Robert Truax, who had been championing rocket propulsion in the Navy, strongly and bluntly told the members at their annual meeting that they were too complacent in their attitude toward space flight, that time was catching up with them, and that

*Hall, R. C., "Early U.S. Satellite Proposals," *Technology and Culture*, Vol. 4, No. 4, Fall 1963, pp. 23–27. This essay was the winning essay of the Robert H. Goddard Historical Essay Competition for 1962, sponsored by the National Rocket Club of Washington, D.C.

† Hall, pp. 28–33.

‡ Hall, pp. 35–37.

§ Hall, pp. 40–41.

the time for definite action had come. As a consequence of this meeting, the American Rocket Society formed the Ad Hoc Committee on Space Flight.

In 1954, this committee proposed that the government sponsor the building of a small scientific satellite and use available military hardware to launch it. This proposal was submitted to Dr. Alan Waterman of the National Science Foundation, which adopted it. The International Scientific Committee of the National Science Foundation, in making plans for the International Geophysical Year (IGY), recommended that the launch of small scientific satellites be considered by individual groups preparing their own programs for the IGY. The United States National Committee for the IGY also formed a group to study the possibility of having an earth satellite launched as part of the U.S. program. Interest in satellite projects had also revived among the military, and the Army and the Navy had embarked in early 1955 on a joint program (Project Orbiter) to launch an elementary, uninstrumented satellite in two or three years.

It was in 1954 that the International Geophysical Year (1957–1958) was proposed. That summer, the International Scientific Radio Union and the International Union of Geodesy and Geophysics adopted resolutions calling for the launch of an artificial earth satellite during the forthcoming IGY. Both the United States and the Soviet Union picked up this proposal. On July 29, 1955, the White House announced that the United States would launch "small, unmanned, earth-circling satellites as a part of the U.S. participation in IGY." The next day the Soviet Union made a similar announcement.*

THE VANGUARD PROJECT

This announcement of the proposed satellite launchings was the product of coordinated efforts within the National Academy of Sciences, (NAS), the National Science Foundation, (NSF), and the Department of Defense. The announcement stated that NAS would determine the experiments to be orbited, NSF would supply the necessary funds, and DOD would launch the satellite. A Committee on Special Capabilities was established inside DOD to determine the means for launching the U.S. satellite. This group, under the direction of Homer J. Stewart, had three proposals from which to select. One proposal was based on the as-yet-incomplete Atlas missile, one on the Army's Redstone, and one on the Navy's Viking. The Navy proposal was based on research undertaken by the Naval Research Laboratory (NRL) and the Martin Company, builders of the Viking, on a multistage rocket; in essence it would use the Viking as a first stage, the Aerobee as a second stage, and an as yet undetermined rocket as a third stage. After lengthy deliberation, the Stewart committee recommended the NRL proposal in August 1955. The recommendation was accepted and endorsed by the Policy Committee of DOD. A program under Navy management and DOD monitoring was established and designated as "Project Vanguard." The objectives of this Navy program were:

1. To develop and procure a satellite-launching vehicle.
2. To place at least one satellite in orbit during IGY.
3. To accomplish one scientific experiment with the satellite.
4. To track the satellite's flight to demonstrate that it had actually attained orbit.

The basic features of the NRL proposal, later Project Vanguard, were as follows:

1. The first stage was to be based on the Viking rocket, which had been developed by the Navy to replace the dwindling supply of captured V–2's.
2. The second stage was to be an improved Aerobee rocket.
3. The third stage was to be a solid-fuel rocket weighing about 500 pounds, thereby necessitating a real advance in the existing solid-fuel rocket technology.
4. On top of this vehicle would be placed a nose cone weighing 20 pounds, including the scientific experiment to be orbited.

On September 9, 1955, Project Vanguard was officially authorized when the Department of Defense notified the Secretary of the Navy to

*Emme, E. F. *"Aeronautics and Astronautics, 1915–1960,"* NASA, Washington, D.C., 1961, p. 78.

Project Vanguard Staff.

Members of the Project Vanguard staff meet with Dr. John P. Hagen, Director of Project Vanguard at the U.S. Naval Research Laboratory, Washington, D.C. Left to right: Dr. J. N. Siry, Head of the Theory and Analysis Staff; Mr. D. G. Mazur, Manager of the Vanguard Operations Group at Cape Canaveral, Florida; Mr. J. M. Bridger, Head of the Vehicle Branch; Cdr. W. E. Berg, Navy Program Officer; Dr. Hagen; Dr. J. P. Walsh, Deputy Project Director; Mr. M. W. Rosen, Technical Director; Mr. J. T. Mengel, Head of the Tracking and Guidance Branch; and Dr. H. E. Newell, Jr., Science Program Coordinator. Mr. L. Winkler, Engineering Consultant, was not present when this picture was taken.

proceed with the project. Two years, six months, and eight days later (March 17, 1958) the first successful Vanguard satellite was launched.*

At NRL, a special task force, headed by Dr. John P. Hagen, was assembled to handle the Vanguard program. In a letter to the Navy Department, this group clarified its definition of what Project Vanguard really would be: "a complete system for space exploration." They had a difficult task before them. In addition to the rocket technology involved, they had to place a reliable scientific experiment into orbit and not only prove that it was in orbit but gather data from the satellite via telemetry. This had never been done before.†

Dr. Hagen's NRL team had mountains of problems to overcome. One difficulty might be used for illustration. At the Martin Company, which NRL had selected to build the Vanguard missile, the original Viking engineering team had been broken up. Further, unknown to the Navy, the Martin Company had received a prime contract from the Air Force to develop the second-generation ICBM, Titan. Some of the leading Viking engineers already had been placed on this project. This was, as Dr. Hagen noted, "a shock, as we had cleared our intentions with the DOD before letting our letter of intent." The Navy stuck with the Martin Company, but "things could have been much easier for the Vanguard group if the original Viking team of Martin had remained intact."†

While the Navy was busy preparing the launch vehicle, the National Academy of Sciences established a technical panel, under its IGY committee, to select the experiments to be launched. The Vanguard group, through the liaison of Homer E. Newell, insisted on only one requirement for each experiment: that it must have a very high reliability of performance and must be tested thoroughly to prove this reliability.

The National Academy of Sciences requested the Vanguard group to make the satellite spherical in shape; in fact, a 30-inch sphere was requested. This caused some difficulty, as it originally had been planned that Vanguard would orbit merely a simple nose cone. The Vanguard group agreed that they could change their design to launch a 20-inch sphere, but this would require a complete redesign of the second stage, which would have to have a larger diameter. Therefore, in the fall of 1955, a redesign of the Vanguard vehicle was undertaken to fulfill the new requirements.‡

*Hagen, pp. 43–45.

† Hagen, p. 45.

‡ Hagen, p. 46.

By March 1956, the redesign of the Vanguard rocket was completed and a full schedule of six test vehicles and seven satellite-launching vehicles was prepared. As prime contractor for the launch vehicle the Martin Company was constructing the first stage; Aerojet Corporation received a subcontract for the second stage; and the Grand Central Rocket Company and the Allegany Ballistics Laboratory were each building separate third stages based on different designs. Two major problems remained to be solved: choosing a launch site, and constructing the necessary tracking system.*

With the rocket power then attainable, it was virtually mandatory that the satellite be launched eastward in order to gain, rather than lose, the earth's rotational velocity of some 1300 feet/second (about 1000 mph). An eastward launching could be made only from the east coast, lest the spent rocket stages fall on inhabited areas. This ruled out the otherwise most natural launch site, White Sands, New Mexico, where the Viking launch facilities were available. The best available site was Cape Canaveral, Florida, which then was being expanded to accommodate the testing of large, liquid-fuel ballistic missiles. The only other serious "competitor" was Roosevelt Roads in Puerto Rico. Cape Canaveral was selected for many reasons, the main one being financial. However, a number of problems arose from this selection. When the Navy requested that the Army share its facilities at the Cape with the Vanguard operation, the Army refused on the grounds that it would interfere with the Redstone program and thus be detrimental to the nation's ballistic missile program. It was then decided that the Navy would construct its own blockhouse and launch pad at Cape Canaveral. This was an 18-month program but was still within the limited time remaining to complete launch during IGY. Additional down-range facilities also had to be constructed because the Vanguard rocket, unlike the Army's ballistic missile of that day, was a multistage affair requiring command and control points as far away as a thousand miles from the launch site. Even a gantry (service tower) was unavailable; the Vanguard group had to disassemble the Viking gantry at White Sands, transport it to the Cape, and reassemble it there. By the time of the first launch, the Navy's Vanguard group had constructed the nation's first complete satellite launch facility, almost from the ground up.†

Tracking facilities proved to be a problem. Two types of tracking were necessary: electronic, and optical. The electronic tracking system necessitated a series of ground stations equipped with radio transmitting and receiving equipment, radar facilities, and data-acquisition (telemetry) equipment. These facilities had to be constructed before the launch could take place and had to be located all over the world to provide the complete coverage considered necessary. A contract was awarded to the Bendix Corporation to construct this system, which later became known as Minitrack (for *Minimum Weight Tracking*, because it required only the simplest and lightest transmitter in the satellite). A system of optical tracking stations was established and managed by the Smithsonian Astrophysical Observatory. Tying all this together was a communications network with the center at the Naval Research Laboratory, Washington, D.C.‡

The twelve Vikings had been built and fired in the normal course of NRL's upper atmosphere research. Viking 13 was at White Sands awaiting preparation for launch when the Navy was given the Vanguard mission. Viking 14 was modified by adding an ejectable sphere and by adding a solid-fuel second stage to test its ignition and separation at altitude. This vehicle was designated as Test Vehicle 1 (TV–1). It was then decided to use Viking 13 to check out the new launch facilities at Cape Canaveral. To make this the first of the Vanguard series and to eliminate confusion resulting from any need to renumber all the vehicle designations, Viking 13 was placed ahead of the rest of the planned series and designated Test Vehicle 0 (TV–0).§

On December 8, 1956, TV–0 was successfully launched at Cape Canaveral. It reached an altitude of 126 miles and dropped into the ocean 183 miles away. TV–1 was launched on May 1,

*Hagen, p. 46.

† Hagen, pp. 47–48.
‡ Hagen, pp. 48–49.
§ Hagen, pp. 49–50.

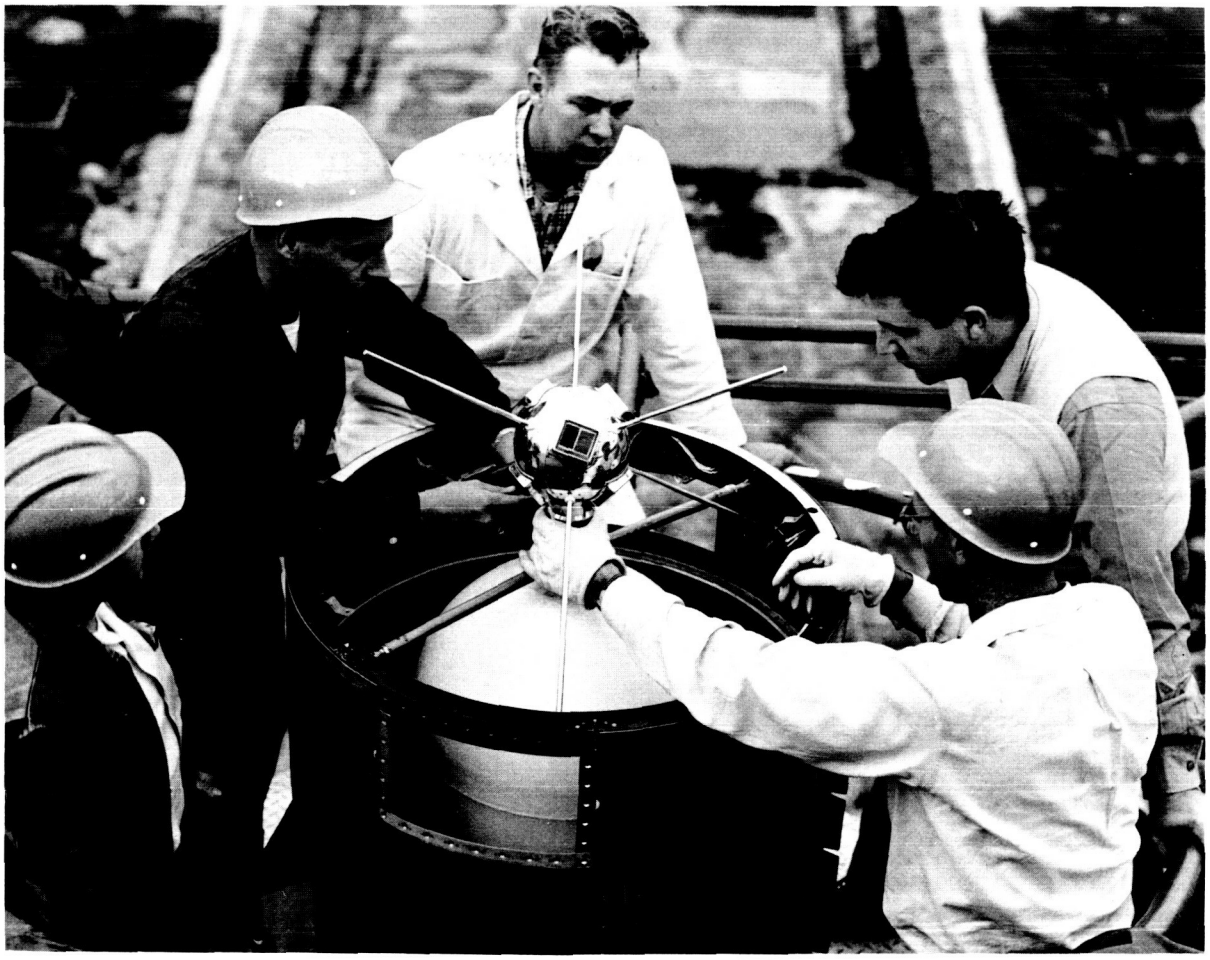
1957; this was a redesigned rocket and the only one of its kind flown. The first stage was the Viking 14; the second stage (which was actually the Vanguard third stage) ignited, separated successfully, and flew 450 miles farther, carrying a heavy instrumented nose cone. A milestone had been reached; a solid-fuel upper stage had been ignited in flight, and the feasibility of the Vanguard rocket had been proven.

In July 1957, an important change was made in the Vanguard program; NLR directed that Vanguard replace the instrument test packages previously flown on its test vehicles with small (6-inch) satellite spheres. Emphasis was changing from the testing of launch vehicles to the launching of satellites. This alteration was not made on TV–2 (the first of the true Vanguard first stages); this rocket was already on the launch stand going through prelaunch checkout when, on October 4, it was announced that the Soviet Union had launched an earth satellite.*

AFTER SPUTNIK

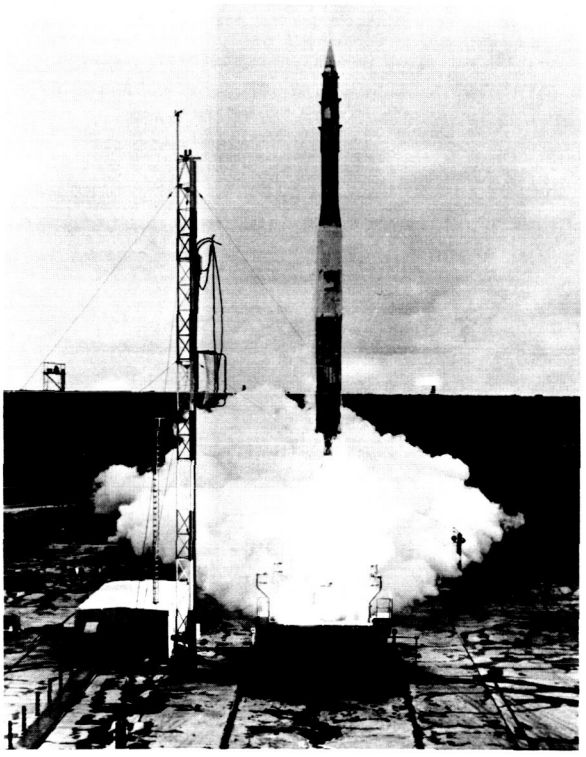
The launch of Sputnik I caused a great deal of turmoil in the United States. Great pressure was exerted on the Vanguard team to get a satellite into orbit. The launch of TV–2 on October 23, 1957, appeared to be anticlimactic, but it was the first successful launch of the complete Vanguard configuration and flight test of the first-stage engine. On December 6, an attempt was made to launch TV–3; this was the

*Hagen, p. 50.



Vanguard technicians mate Vanguard I satellite to rocket for its successful flight on March 17, 1958.

first test of the complete vehicle and control system and was the first Vanguard rocket with potential orbital capabilities. The first-stage engine lost thrust after 2 seconds (its first and only failure), and the vehicle burned up on the launching pad. Because of the impact of Sputnik and because the White House had announced prematurely that Project Vanguard would launch a satellite in the near future, news of this failure went around the world. The launch of the first U.S. satellite, Explorer I, on January 31, 1958, by the Army and the breakup of the TV–3 backup vehicle on February 5, after 1 minute of flight, brought more unkind comments about the first U.S. satellite program.*



Vanguard I liftoff, March 17, 1958.

On March 17, 1958, TV–4 successfully launched Vanguard I, a 6-inch sphere weighing only 4 pounds. Although this was far from the final objective of a 20-pound instrumented satellite, the confidence which had been placed in the Vanguard project was justified. The launch of TV–4 confirmed the merit of the Vanguard rocket design, and illustrated that the Vanguard group had developed into a well-integrated professional and technical team. Three other Vanguard rockets were launched before the Vanguard team was transferred from NRL to the newly created civilian space agency, NASA. The first (SLV–1), launched May 27, 1958, generally was successful except for a second-stage burnout; in the second (SLV–2), launched June 26, 1958, the second stage cut off prematurely; the third (SLV–3), launched September 26, 1958, reached an altitude of 265 miles.

*Hagen, pp. 50–51.

VANGUARD AND NASA

The launch of Sputnik I in the fall of 1957 had been a real jolt to the complacency of the American people. In true American tradition, a great clamor went up as to *why* the Soviet Union was ahead of the U.S., *who* was to blame for the situation, and *what* was to be done about it. The people engaged in existing satellite programs had a difficult time explaining that their best efforts had been hampered by limitations over which they had no control. However, the end results of the new "space consciousness" were very beneficial, since there developed a general realization that the American effort had to be greatly expanded and financially supported.

About six months after the launch of the first Sputnik, the President's Science Advisory Committee and the President's Advisory Committee on Governmental Organization recommended the establishment of a civilian agency to direct nonmilitary space activity. President Eisenhower delivered a message to Congress on April 2, 1958, which stated that "aeronautical and space science activities sponsored by the United States should be conducted under the direction of a civilian agency except for those projects primarily associated with military requirements." As a result of this message and a clear public demand for such action, Public Law 85–568, the National Aeronautics and Space Act, was enacted and signed by the President on July 29, 1958. This law established the National Aeronautics and Space Administration and gave the new agency the responsibility for conducting the scientific exploration of space for peaceful purposes. The

law also gave the President the authority to transfer to NASA "any function of any other department or agency of the United States, or of any officer or organizational entity thereof, which relate primarily to the functions, powers, and duties of . . . NASA." This new agency, NASA, opened its doors on October 1, 1958. Project Vanguard was transferred to NASA, along with other DOD space projects.*

Vanguard III, launched September 18, 1959.

The Vanguard project was continued under the direction of NASA. Vanguard II (SLV–4), launched on February 17, 1959, was the first full-scale (21-pound) Vanguard payload to achieve orbit. It was also the first satellite designed to observe and record the cloud cover of the earth and was a forerunner of the Tiros weather satellites. Vanguard III (SLV–7), launched on September 18, 1959, was a 20-inch sphere weighing about 50 pounds.

*Emme, E. M., "Historical Origins of NASA," NASA Historical Report No. 6, NASA, Washington, D.C., 1962, pp. 1–3.

VANGUARD HELPED SHAPE THE FUTURE

As it happened, Vanguard I was not destined to be the first U.S. satellite. However, its contributions to the U.S. space effort were great indeed. The Vanguard program produced a basic concept of launch vehicles, including the remarkably reliable Delta. Vanguard pioneered the use of advanced state-of-the-art techniques, including the first utilization of solar cells as a power source, which have become commonplace components of American satellites. The scientific experiments which were flown on the Vanguard satellites increased the amount of scientific knowledge of space and opened the way for more sophisticated experiments.

Perhaps the most significant achievement of Project Vanguard was the bringing together of a group of dedicated and talented scientists and engineers who came to understand thoroughly the complexities and challenges of the space sciences program. This team was assimilated into the National Aeronautics and Space Administration, where it became the human core of the Goddard Space Flight Center and served as the foundation for the distinguished space sciences programs which emerged from this Center.†

Two interesting sidelights to the Vanguard project may serve to illustrate both the difficulties of the program and its successes. Project Vanguard was accomplished without a specific appropriation from the U.S. Congress. All of the funds came from the Secretary of Defense's Emergency Fund. Only after Sputnik I had been launched and the Vanguard project had reached its final stages of completion did Congress authorize the Secretary of Defense to make available additional funds for the attainment of the Vanguard objectives by reprogramming the Defense Budget. The total Vanguard project cost $110 million. Finally, on the fifth anniversary of its launching (March 17, 1963), Vanguard I was still transmitting and was the only satellite launched before 1959 that was yet in orbit. Vanguard I had made 19,700 orbits and now has an estimated lifetime of 2000 years.

† Hagen, pp. 51–53.

Chapter 3

ESTABLISHMENT OF THE GODDARD SPACE FLIGHT CENTER

On September 25, 1958, Dr. T. Keith Glennan, Administrator, in a proclamation published in the Federal Register* announced the activation of the National Aeronautics and Space Administration (NASA) to be effective October 1, 1958. The approximately 8000 people and five laboratories of the 43-year-old National Advisory Committee for Aeronautics (NACA) were to be assimilated into the new agency. NACA's facilities would then become NASA's facilities, including Wallops Island (Va.) Station and four research centers: Langley Research Center (Hampton, Va.), Lewis Research Center (Cleveland, Ohio), Ames Research Center (Moffett Field, Calif.), and the Flight Research Center (Edwards Air Force Base, Calif.).

On October 1, 1958, an executive order of the President (EO 10783)† effected the transfer to the National Aeronautics and Space Administration of the responsibilities involving several space research projects, including the Navy's Vanguard project.

By this executive order, 157 Project Vanguard personnel were transferred from the U.S. Naval Research Laboratory to the National Aeronautics and Space Administration.‡ The transfer became effective on November 30, 1958, and this group became known as the NASA–Vanguard Division. In December 1958, this group was organically transferred from the Naval Research Laboratory to the Space Science Division of NASA. During December 1958 and January 1959, 15 people from the Naval Research Laboratory were transferred to the Theoretical Division of NASA. Early in 1959, these elements were designated by NASA Headquarters to serve as the nucleus of a new Space Projects Center. Its staff was housed at the Naval Research Laboratory, Washington, D.C., and at the Colemont Building, Silver Spring, Md.

This group was thus composed of some of the most experienced men who had been engaged in space research. It included upper atmosphere scientific research teams and scientists and engineers from all three military services, the Project Mercury (manned satellite) team culled from the experienced staff of the former NACA laboratories, and the Navy's Project Vanguard staff. These groups gave immediate, mature capabilities in many vital areas of space flight research and development, since each was a "going concern" when the transfer was made. From these and other groups, the initial team of senior personnel, around which was built the organization for the new Space Center, was assembled.

THE NEW BELTSVILLE SPACE CENTER

On January 15, 1959, by action of the NASA Administrator,§ four divisions (Construction Division, Space Sciences Division, Theoretical Division, and the Vanguard Division) of NASA were designated as the new Beltsville Space Center.

On January 22, 1959,‖ a NASA General Notice announced the establishment of the Beltsville Space Center to be operated under the direction of the Director of Space Flight Development, NASA Headquarters, Dr. Abe Silverstein.

*Appendix D, Exhibit 2.

†Appendix D, Exhibits 3 and 4.

‡Appendix D, Exhibit 5.

§ Appendix D, Exhibit 6.

‖ Appendix D, Exhibit 7.

In a meeting held on February 12, 1959, for the purpose of surveying the organization and functions of the Beltsville Space Center,* it was generally agreed that the Center probably would perform five major interrelated functions on behalf of NASA:

Project management
Research
Development and fabrication
Advanced planning
Operations

Some of the assignments, active or to become active within the next 18 months, were:

Science Program

155 Science rockets of various types
30 Satellites
15 Probes

Application Satellites

Communications and meteorological, six or seven vehicles
Geodetic—undetermined number of satellites
Other Vanguard Division follow-on programs

Project Mercury

Phase I
Phase II

Vehicles and Engines

Vega
Centaur
Thor–Vanguard (Thor–Delta)
Juno V (1.5-Meg bundle)
Nova (1.6-Meg engine, currently known as 1.0-Meg engine)

Global Range and Operations

Space communications and trading
Operational telemetering
Ranges—Wallops Island, Atlantic Missile Range, Pacific Missile Range

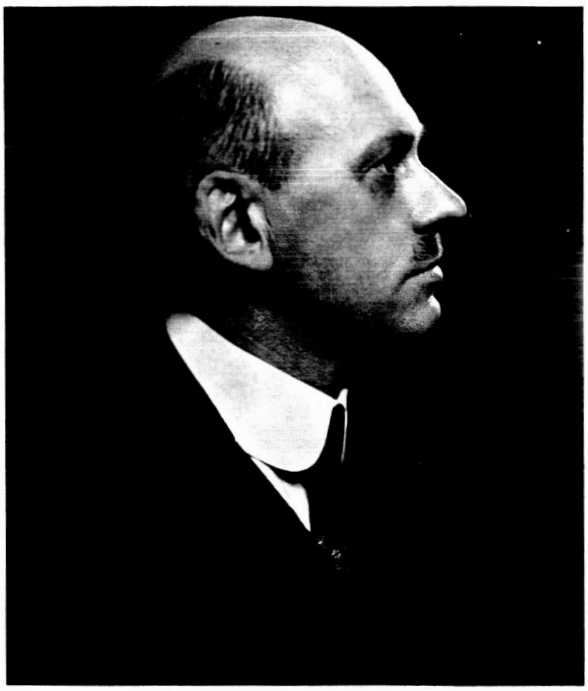
It was determined further that existing groups at the Division level had capabilities in the following areas:

Space sciences
Vehicle systems
Theoretical research and support
Instrumentation support
Payload systems
Data handling and techniques
Communications and tracking
Operation

*See Appendix D, Exhibits 8 and 9.

BELTSVILLE BECOMES GODDARD

On May 1, 1959, the Beltsville Space Center was renamed the Goddard Space Flight Center. On this date, T. Keith Glennan, NASA Administrator, in a public release, formally announced that the new center would be named the Goddard Space Flight Center "in commemoration of Dr. Robert H. Goddard, American pioneer in rocket research." The Center would be under the overall guidance of the Director of Space Flight Development at NASA Headquarters.



Dr. Robert H. Goddard.

The organization of Goddard Space Flight Center (GSFC) was to include a director, not yet appointed; three major research and development groups, each headed by an assistant director; and business administration and technical services departments.

In the announcement, John W. Townsend, who was Chief of NASA's Space Sciences Division and who earlier had served as Chief of the Rocket Sonde Branch of the Naval Research Laboratory, was named Assistant Director for Space Science and Satellite Applications. John T. Mengel, who was responsible for the develop-

ment of the Project Vanguard Minitrack system used for satellite tracking, was named Assistant Director for Tracking and Data Systems. Robert R. Gilruth, who had been Chief of the Pilotless Aircraft Research Division, Langley Research Center, was named Assistant Director for Manned Satellites. The three Assistant Directors reported to the Director of Space Flight Development, NASA Headquarters, Dr. Abe Silverstein. The announcement also stated that the Office of Business Administration would be headed by Dr. Michael J. Vaccaro, transferring from the NASA Lewis Research Center, Cleveland, Ohio, where he had served as Director of Organization and Personnel. This was the first formal announcement of the Goddard organization, mission, and appointment of key personnel.*

Listed here, in brief form, are the responsibilities assigned to GSFC:

- Conducting advanced planning and theoretical studies
- Conducting necessary supporting research
- Developing payloads for approved programs
- Supervising GSFC flight operations
- Supervising tracking, data acquisition, communications, and computing operations
- Interpreting results of flight programs
- Furnishing technical management of projects
- Exercising procurement and contract administration authority
- Providing support of space program activities of other organizations
- Reporting status of approved programs
- Providing administrative and management support

With the new space agency specifically responsible for activities in space devoted to peaceful purposes, the question arose as to which space programs initiated by the Department of Defense under its Advanced Research Projects Agency should be continued by NASA. Spacecraft and meteorological satellites had been developed by the Army Signal Corps' Research and Development Laboratory, Fort Monmouth, New Jersey; the vehicle development had been under the Army's Ballistic Missiles Command. Upon transfer of the meteorological program to NASA, the mission was assigned to the Goddard Space Flight Center. The space communications program also had been a project of the military. Initially the satellite communications program utilized the passive balloon technique with experiments conducted by the Army Signal Corps at Fort Monmouth and at NACA's Langley laboratory. With creation of NASA and the establishment of the Goddard Space Flight Center, communications projects also were assigned to the new center.

In September 1959, Dr. Harry J. Goett was named Director of the Goddard Space Flight Center. He came to the Center from the Ames Research Center, Moffett Field, Calif., where he had been Chief of the Full Scale and Flight Research Division.

In October 1959, Leopold Winkler, who had joined NASA when the Vanguard program was transferred, assumed the position of GSFC Chief of Technical Services.

Somewhat interesting is the early fiscal history of the Center. The executive order transferring the Project Vanguard to NASA also transferred remaining project funds totaling approximately $6 million plus about $300,000 earmarked for special equipment ordered earlier by the Navy's Vanguard staff. These funds became available to the newly established Center, as were certain moneys which had been appropriated to NACA. However, these funds were inadequate to meet the Center's needs. Since the Independent Offices Appropriations Bill already had cleared the U.S. House of Representatives, the Bureau of the Budget authorized the budget request to be included in the 1959 Independent Offices Appropriations Bill as a supplemental item while the bill was being considered by the U.S. Senate. The item was subsequently considered by the House–Senate Conference Committee without further referral to the House.

The fiscal year 1960 budget without the Manned Space Flight Program totaled somewhat less than $100 million (the manned flight program was about $140 million, giving a total

*Appendix D, Exhibits 10 through 14.

budget for the Center of about $240 million). The program mushroomed again in fiscal year 1961 to about $160 million (an additional $140 million was designated for the manned space missions). The Center's program for fiscal year 1962 came to about $250 million; that for the fiscal year 1963 was expected to total about $400 million.

Contractual operations, which became a vital and integral part of Goddard's business operations, were handled for the Center by NASA Headquarters during the early period of its development.

As previously indicated, NASA's Manned Space Flight Program was an integral part of the Goddard mission. For this mission, the Center had the talent and technical capabilities from the early Vanguard days, including a worldwide Minitrack network. However, in view of increasing emphasis in the areas of scientific and application satellite projects and the recognition that the Manned Space Flight Program demanded a separate organization, that mission was transferred as of January 1, 1961. The Center retained its responsibilities in connection with the Project Mercury tracking network. As a result of this transfer of responsibilities, approximately 840 people left the Goddard staff to form the nucleus of what later became NASA's Manned Spacecraft Center, located near Houston, Texas.*

Meanwhile, on April 24, 1959, construction of the new space laboratory began on a site located on a 550-acre tract formerly part of the U.S. Department of Agriculture's Agricultural Research Center at Beltsville, Md. By September 1960, Building 1 was fully occupied and other buildings were well underway. Although much of the occupancy was on a temporary basis and the personnel complement was widely scattered from Anacostia, D.C., to Silver Spring, Md., and points between, the Goddard Space Flight Center became a physical reality.

THE DEDICATION

On February 8, 1961, Dr. Harry J. Goett, the Director, announced dedication ceremonies to be held on March 16, 1961. A committee with Dr. Michael J. Vaccaro as Chairman and Robert C. Baumann as Co-Chairman planned the dedication ceremonies.

The dedication ceremonies included an opening address by Center Director Dr. Harry J. Goett, and a welcoming address by the Hon. James E. Webb, Administrator, National Aeronautics and Space Administration. The event also marked the presentation of a Congressional Medal awarded posthumously to Dr. Goddard, which was accepted by his widow; the presentation was made by Representative Overton Brooks, Chairman, Committee on Space and Astronautics, U.S. House of Representatives.

Dr. Goett, in his opening address, acknowledged the contributions made by many in the audience toward the creation of the Center.

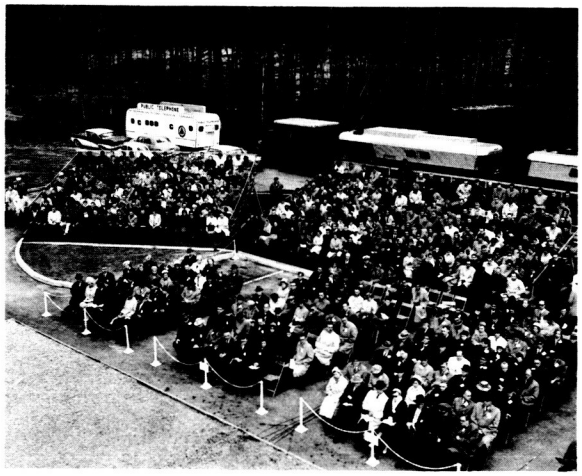
The Hon. James E. Webb in his welcoming address expressed his pleasure for the presence of Mrs. Goddard and prominent officials and interested friends.

In presenting the Congressional Medal, Representative Brooks said, "From the Congress of which I am Chairman of the House Committee on Space and Aeronautics, we present this medal, but truly it comes not from the Congress of the United States but from the heart . . . of the American people as a whole." Senator Robert S. Kerr, Chairman of the Committee on Aeronautical and Space Sciences of the U.S. Senate, was unable to be present but sent the following message to Mrs. Goddard: "Mrs. Goddard, I am more than honored to have the opportunity of joining my good friend, Overton Brooks, in presenting to you this Congressional Medal in recognition of the creative achievements of your late husband. It was just 35 years ago today that he launched the world's first successful liquid fuel rocket and it is most appropriate that we make this presentation on this auspicious anniversary. It is only through the genius of a man like Dr. Goddard, who was not afraid to work for what he believed in, that we shall maintain the spirit and vitality that has made our Country great. This medal, authorized by Congress on behalf of all the people, is but a small token from a grateful nation."

Dr. Hugh L. Dryden, Deputy Administrator, National Aeronautics and Space Administration, introduced Dr. Detlev W. Bronk, Presi-

* Grimwood, J., "Project Mercury—Chronology," NASA SP-4001, September 1963.

Dedication Ceremony, March 16, 1961.



Dignitaries and guests attending the Center's dedication.

dent, National Academy of Sciences, who made the dedication address.

Dr. Bronk said in part: "There are two quotations I would like to repeat. The one appropriate to the Mission of this institution, the other with regard to the man we honor. The first is from Louis Pasteur, speaking at a time when his beloved country was not doing well, 'Oh, my Country,' said he, 'You who so long held the sceptre of thought, why did you neglect your noblest creations? Take interest, I beseech you, in those sacred institutions which we designate under the expressive name of Laboratories. Demand that they be multiplied and adorned for they are the temples of wealth and of the future. There it is that humanity grows, becomes stronger and better . . . it learns to read in the work of nature symbols of progress with universal harmony,' and from Pliny the Younger, 'It is a noble employment to save from oblivion those who deserve to be remembered'."

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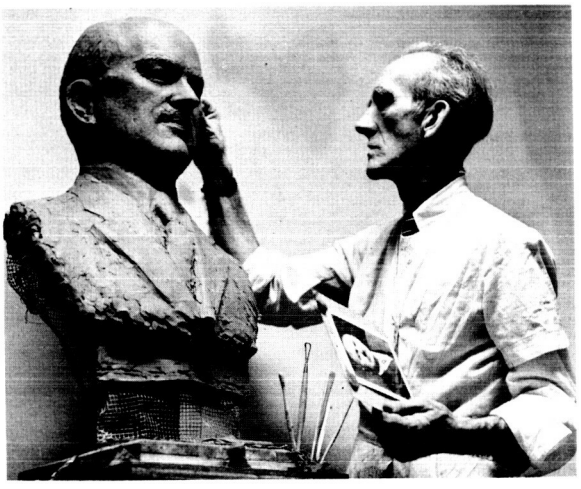
A bronze bust of Dr. Robert C. Goddard was unveiled by his wife, Mrs. Esther C. Goddard, assisted by Dr. Abe Silverstein, NASA Director of Space Flight Programs. The bust was created by the Washington sculptor, Joseph Anthony Atchison, noted for his creative work in the Shrine of the Immaculate Conception in Washington, the World Flight Memorial for the Smithsonian Institution, and the Second Inaugural Medal of Franklin D. Roosevelt.

Responding to the recognition paid her late husband, Mrs. Goddard remarked: "I hope that this bust and the man it represents will serve as an inspiration not only to the brilliant and dedicated people who are now at work at this tremendous Space Flight Center but to all who may work here in years to come. My husband would be deeply proud and happy for this very great tribute."



Joseph Anthony Atchison at work on the bust of the late Dr. Robert H. Goddard.

The invocation at the dedication ceremony was given by the Rev. Kenneth B. Wyatt of the Greenbelt Community Church, and the benediction at the ceremony's close by the Rev. Victor J. Dowgiallo, Pastor of St. Hugh's Church, Greenbelt.

The music was furnished by the University of Maryland Band, directed by Mr. Hugh Henderson.

Tours of the Center were conducted for invited guests, and "open house" was held for employees and their families. Included was a Control Room demonstration with simulation of a pre-rocket-launch and countdown procedures, followed by a simulated satellite injection into orbit.

Lectures reviewed the Center's operation of global satellite networks, including Minitrack and Project Mercury. The cooperative role of the Center in the international exploration of space was explained. Guests saw an animated miniature tracking station and a scale model of the forthcoming U.S./U.K. spacecraft, Ariel I, the first international satellite to be flown under Goddard project direction.

There were also displays of spacecraft instrumentation and Goddard's family of sounding rockets, including an Aerobee 150A with a new attitude control system.

Other models on display included the Tiros weather satellites; Explorer X, the magnetometer (or radiation-counting) spacecraft; the Energetic Particles Satellite; Explorer VIII; and Vanguard I. There was also a demonstration of a micrometeorite detector. Vacuum, vibration, and spin-balancing equipment used to simulate space environmental conditions was shown.

Under authorization for construction at the time of dedication were eight buildings which would provide the necessary facilities for 2000 scientific, technical, and administrative personnel—representing a $27 million investment. The 550-acre tract once devoted to agricultural research was given a new mission. There was rapidly emerging the nation's first center to be devoted to the peaceful exploration of space.

Mrs. Robert C. Goddard participating in ceremonies dedicating the Center named in honor of her late husband.

Part II

GODDARD SPACE FLIGHT CENTER GOES TO WORK

Nature to be commanded must be obeyed.
—Francis Bacon

The wooded site selected for the space center.

Chapter 4

THE EARLY YEARS

This chapter will go somewhat beyond a discussion of the traditional concepts that the "3 M's" of Management are *Men*, *Money*, and *Machines* and present some of the operational concepts which have been developed and applied at the Goddard Space Flight Center. Statistics and detailed facts are herein dealt with only to the extent necessary to paint, in broad strokes, the Center's brief history.

While the early years of Goddard were deeply concerned with *Men* (or Manpower), *Money* (in terms of budgetary activity, procurement activity, and operational costs), and *Machines* (in terms of buildings and supporting equipment resources), other factors had far-reaching effects. These included such elements as Goddard's approach to individual project organization, its plan for unifying different disciplines into a group serving a common purpose, its program for disseminating scientific information—and many others.

Dr. T. Keith Glennan, former NASA Administrator, said:* "We are not an operating organization in the ordinary sense of that term. We do not expect to operate meteorological or communications systems. Our product is knowledge—new and fundamental knowledge—and the techniques, processes, and systems by means of which we acquire that knowledge. The rocket-powered launch vehicles we design and buy are not an end in themselves—they are cargo-carrying trucks of space, discarded when their fuel is exhausted."

It follows therefore that, while the direct relation between some particular element or effort of Goddard and the acquisition of space knowledge may sometimes appear tenuous, the fact remains that the primary reason for the Center's existence was, and is, to acquire knowledge. To do so requires the coordinated effort of many scientists, engineers, technicians, and support personnel—often located in remote areas throughout the world—as well as buildings, equipment, and facilities.

The Center's growth may be measured by several factors: (1) the rapidity with which it expanded its work force from a "handful" of people formerly with the Vanguard project at NRL to a staff of about 2850 with widely varied skills and backgrounds; (2) the growth of its physical plant from a wooded area near Greenbelt, Md., formerly a part of the Beltsville Agricultural Research Center of the U.S. Department of Agriculture, to a complex of modern space science laboratories, testing facilities, and worldwide tracking and data acquisition and reduction facilities; and (3) the growth in financial responsibility from the approximately $6,300,000 transferred by the Navy to an annual budget of about $250 million for the 1962 fiscal year.

A NUCLEUS OF 157

The first employees of the activity later designated as the Goddard Space Flight Center were the 157 people of the Vanguard group who were transferred from the Navy to the newly created National Aeronautics and Space Administration.

By mutual agreement between DOD and NASA it was decided that this cadre would remain at the Naval Research Laboratory "until suitable space is available at the projected NASA Space Projects Center in Beltsville." The Project Mercury group, consisting of approximately 250 employees at Langley, also became a part of the initial Goddard organization

*Address of Dr. T. Keith Glennan, Administrator, National Aeronautics and Space Administration to Science, Engineering, and New Technology Committee, Oregon State Department of Planning and Development at Portland, Oregon, on October 12, 1960.

but was later assimilated into NASA's Langley Research Center.

In December 1958, another 46 employees were transferred to the Beltsville Center from NRL's Space Sciences group. By the end of 1958, the new Center had a total of 216 employees. By June 1959, the Center had grown to 391 people in the Washington area. In 1959, the recruitment activities were stepped up significantly, and by the year's end there were 579 employees. By June 30, 1960, through transfer and recruitment the personnel complement had grown to 707 people.

FIRST QUARTER

The temporary quarters at the Naval Research Laboratory soon became entirely inadequate, and additional space was obtained at the U.S. Naval Station, Anacostia, D.C. During this period, the Center's top management staff, which had been located at NASA Headquarters and at the Naval Research Laboratory, was moved and consolidated in these offices at Anacostia.

In the following year total employees had increased to about 1200 and, as of December 31, 1962, over 2850 were employed or committed for employment.

In a labor market which was extremely tight because of the nationwide shortage of scientists and engineers, Goddard had the additional problem of finding interested individuals possessing the specific and unique experience demanded by its mission.

Five separate categories of employees composed the overall Goddard team:

Professional scientists and engineers
"Blue collar" craftsmen
Technical support people
Professional administrators
Clerical personnel

Almost 42 percent of the Center's work force consisted of scientists and engineers. Throughout NASA, the ratio was approximately ⅓ to ⅔ support people. Goddard's group of scientists and engineers was somewhat larger because of the nature of its mission, that is, more theoretical and experimental work in the space science and satellite applications.

PERSONNEL RECRUITING

Experience with the college recruitment program was rewarding. Although entrance salaries may have been somewhat below the national average, the challenge of Goddard's mission, facilities, and progressive educational programs attracted high-quality graduates. The critical recruitment area was that in which highly specialized experience was necessary: for example, senior people with solid experience in satellite instrumentation, communications systems, systems integration, and spacecraft project management. It is somewhat paradoxical that for this group of personnel the Center was, in effect, in competition with itself: It completed with the personnel needs of private companies which, in turn, were also engaged on space projects. One incentive particularly attractive at Goddard was the opportunity provided by the Center to participate in a major space science project from its inception to completion. The Center's mission frequently called for the "universal-type" scientist, capable in areas beyond his immediate discipline of physics, electrical engineering, etc.

Rather than establish, for example, positions as *physicist*, *electrical engineer*, etc., NASA positions were categorized and identified directly with the nature of the work to be done. Since the fields of academic training do not always correspond with the fields of advanced research and development, the aerospace technology concept was applied. Under this plan, the title *Aero Space Technologist* was used to cover the broad field of research and development specialties. Specifically, the titles of such positions had the symbol *AST* followed by the specialty; thus, *AST Fluid and Flight Mechanisms.*

As previously indicated, the scientists and engineers who had been associated with Project Vanguard and other government space programs formed the nucleus of the Goddard Space

Flight Center personnel complement. This group grew as follows:

1959—782 (including staff later transferred to Manned Spacecraft Center)*

1960—1265 (including staff later transferred to Manned Spacecraft Center)*

1961—1497

1962—2850 (Dec. 31, 1962)

*NOTE.—When President Eisenhower assigned responsibility for the development and execution of a manned space flight program, the National Aeronautics and Space Administration was in the process of being organized. Studies and plans for the manned satellite program were presented to Dr. T. Keith Glennan, Administrator, NASA; and on October 7, 1958, he gave orders to proceed with them. In November 1958, the Space Task Group was officially established at Langley Field, Va., for the manned space flight program to be known as the Mercury Project. The Space Task Group was organized under the Goddard Space Flight Center but was administratively supported by the Langley Research Center. It later became evident that the scope and size of the Mercury manned space project were more than sufficient to warrant an entirely separate center and on January 1, 1961, the Project Mercury personnel complement associated with the development and launch of manned spacecraft was transferred to the new Manned Spacecraft Center at Houston, Texas.

Responsibilities for the Project Mercury tracking and data complex remained with the Goddard Space Flight Center.

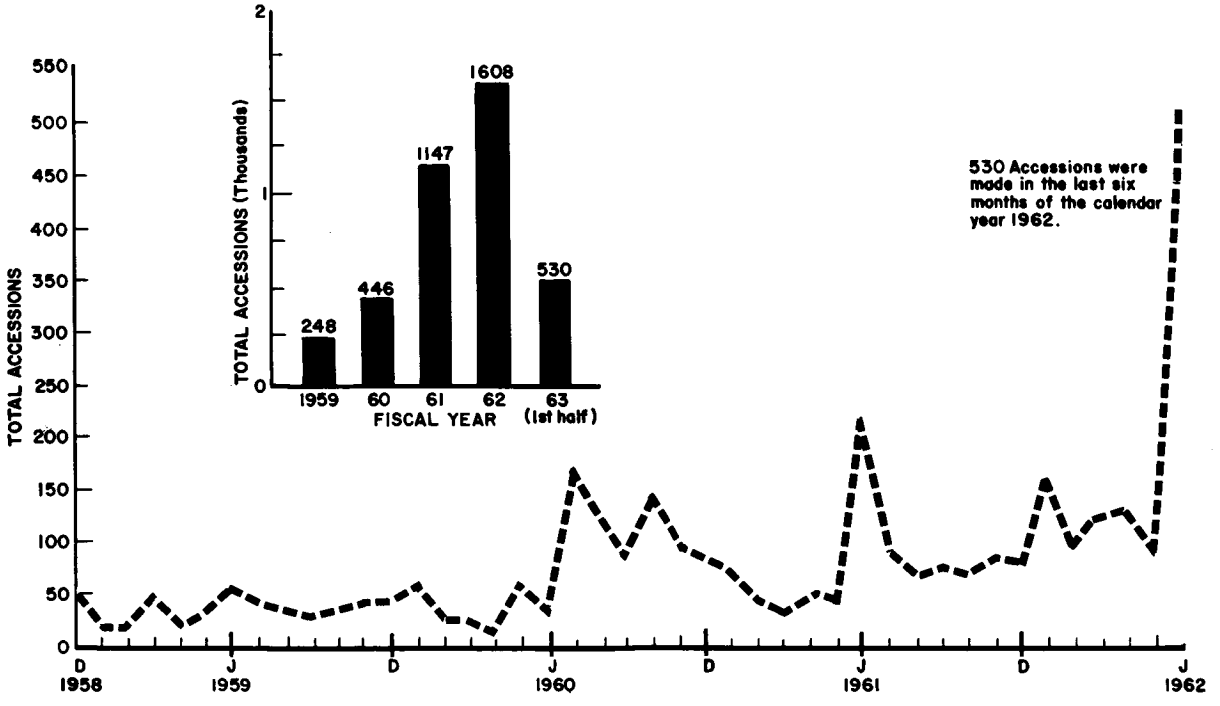
The sources from which scientists and engineers were recruited during the period from December 1958 to December 1962 were as follows:

Government	746	53.8%
Private industry	317	23.0%
Schools	216	15.5%
Other	108	7.8%

Scientists were selected from virtually all sources and from many geographic regions. The recruiting program was conducted with the aid of extensive publicity campaigns and through the cooperation of many colleges and universities.

SCHOOLING CONTINUES

For personnel already on its staff, Goddard sponsored graduate study programs and undergraduate cooperative programs with several colleges and universities. Under the undergraduate cooperative program, selected students who had completed their sophomore year could go to school for one semester and work at Goddard the next, alternating in this way until they get their degrees. Under another plan, graduate students could take three-quarter-credit courses at a local university, wherein they worked three



Total GSFC personnel accessions.

days a week at Goddard and attended classes on alternate days.

Likewise, scientists and engineers were encouraged to continue their educations in one of the several local graduate school programs. Because the field of space technology was unique and developed so rapidly, Goddard had a program of seminars, colloquia, and specialized courses.

Goddard assisted employees who, having completed their studies at the Master's degree level, were striving for greater competence and stature. Each year, the program provided a limited number of carefully selected scientists and engineers with an opportunity to spend up to one year in research and study fellowship programs which they proposed, at institutions of their choice. Fundamentally, this program was a means through which an employee could gain the opportunity to conduct advanced study and research under the direction of men with international reputations in their respective fields.

PERSONAL RECOGNITION FOR SOME

As the Center grew, members of the Goddard staff received personal recognition. Listed here are recipients of honorary awards and patents through 1962.

Honorary Awards

Dr. Joseph W. Siry; Head, Theory and Analysis Office
Arthur S. Flemming Award, conferred February 1961
"For accomplishments in the field of orbit determination and prediction"

William G. Stroud; Chief, Aeronomy and Meteorology Division
Astronautics Engineer Achievement Award, conferred March 1962
"For his personal contribution to the technology of meteorological satellites which are now culminating in rapid development of an operational system"

Bernard Sisco; Deputy Assistant Director for Administration
Distinguished Service Award, Prince Georges County Junior Chamber of Commerce, conferred March 1962
"In recognition of his contributions to the general community welfare during the year"

Robert W. Hutchison; Personnel Director
Federal Civil Servant of the Year—State of Maryland, conferred April 1962
"In recognition of outstanding achievement in contributing to the rapid growth and establishment of the Goddard Space Flight Center"

Robert E. Bourdeau; Head, Ionospheres Branch, Space Sciences Division
NASA Medal for Exceptional Scientific Achievement, conferred October 1962
"For a major scientific advance in the study of the ionosphere and for significant technological progress in the understanding of the plasma sheath about satellites"

Dr. John C. Lindsay; Associate Chief, Space Sciences Division
NASA Medal for Exceptional Scientific Achievement, conferred October 1962
"For the achievement of a major scientific advance in the study of the Sun and for significant technological progress in highly precise satellite attitude control"

Dr. John W. Townsend, Jr.; Assistant Director, Space Science and Satellite Applications Directorate
NASA Medal for Outstanding Leadership, conferred October 1962
"For outstanding and dynamic leadership in planning, developing, and directing a complex scientific organization whose notable achievements have significantly contributed to the pre-eminent position of this country in the space sciences, the development of space technology, and the practical aplication of such research nd development"

The Directorate for Tracking and Data Systems
NASA Group Achievement Award, conferred October 1962
"For superior technical and administrative leadership and outstanding results in the operation of the global manned spacecraft tracking network"

Patent Awards

Stephen Paull, Spacecraft Technology Division
Variable Frequency Multivibrator Subcarrier Oscillator for Telemeter System
November 1960

James L. Albus, Spacecraft Technology Division
Digital Aspect Sensor
February 1962

David H. Schaefer, Spacecraft Technology Division
A Nondestructive Readout Circuit for a Magnetic Binary Storage Element
July 1962

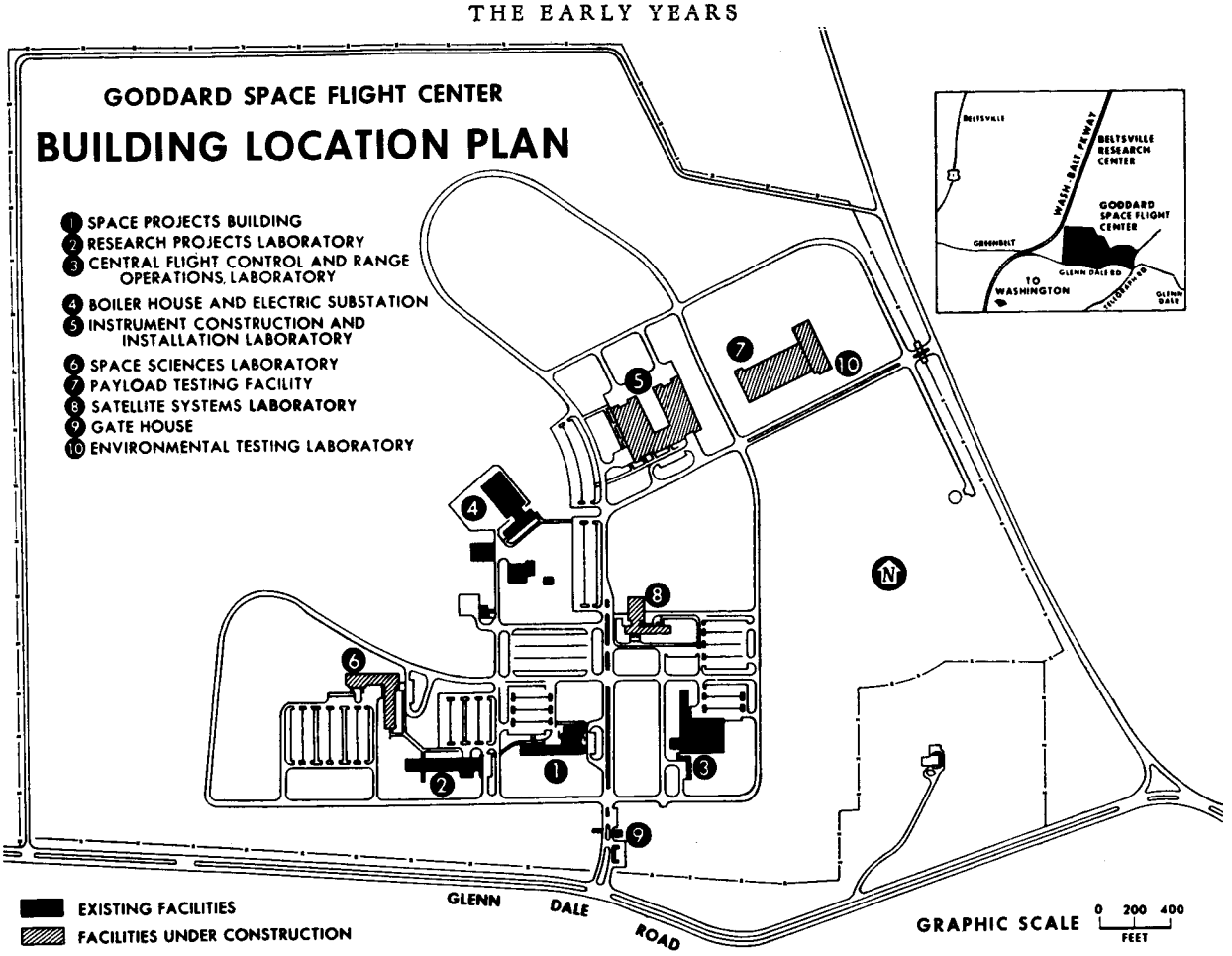
Harold J. Peake, Spacecraft Technology Division
Data Conversion Unit
October 1962

William A. Leavy, Aeronomy and Meteorology Division
Switching Mechanism
October 1962

Stephen Paull, Spacecraft Technology Division
V/F Magnetic Multivibrator
October 1962

PHYSICAL PLANT

The physical plant of Goddard Space Flight Center was established with an eye to present



Location plan of Center, June 1962.

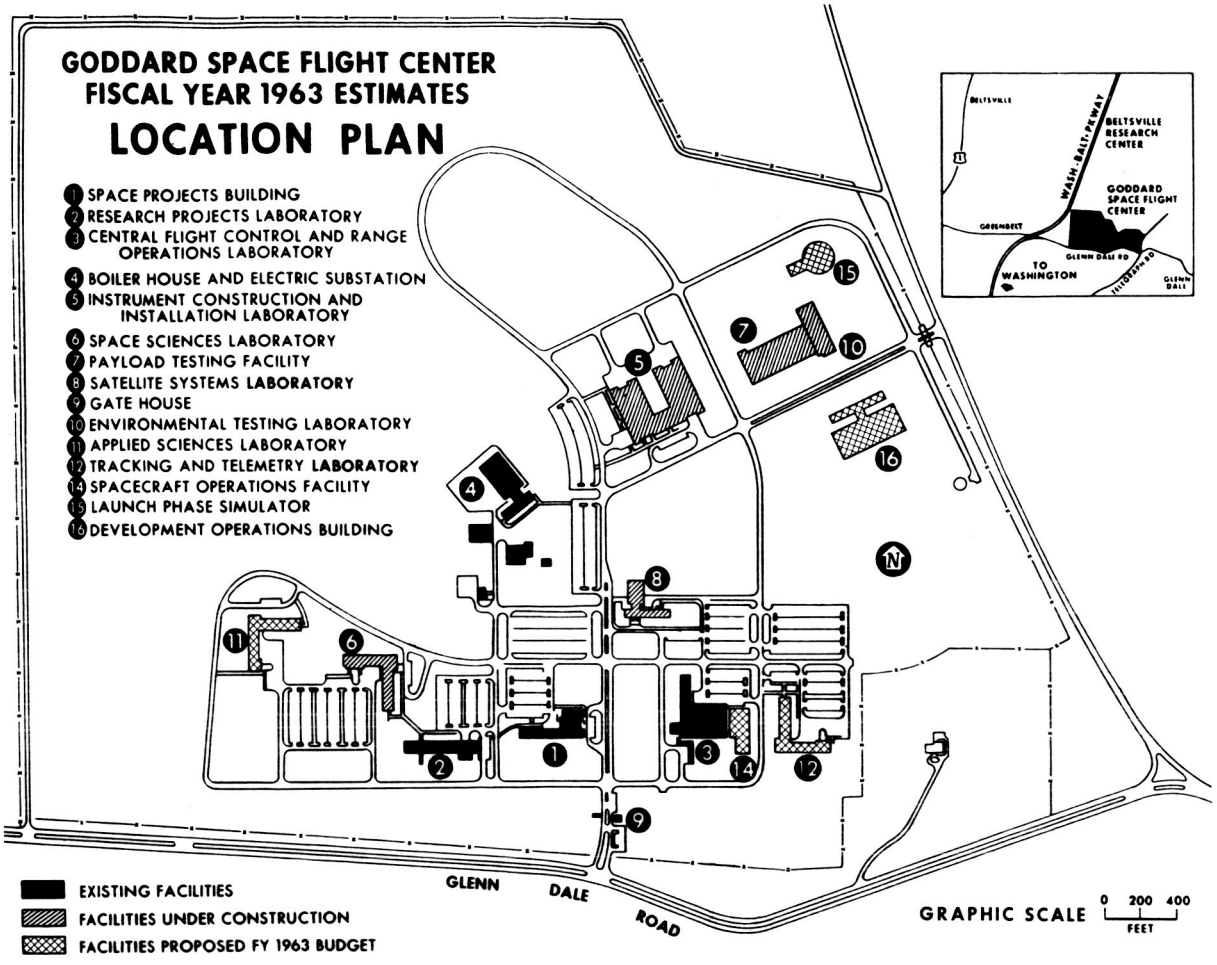
and potential requirements. Its location is on a 550-acre tract of land about 10 miles northeast of Washington, D.C. This tract was formerly a part of the Agricultural Research Center of the U.S. Department of Agriculture, Beltsville, Maryland. The engineering master plan was developed by Voorhees Walker Smith Smith and Haines of New York City.

The first construction contract was let on April 10, 1959, to Norair Engineering Corporation, Washington, D.C. This contract called for construction of Buildings 1 and 2, together with access roads and parking areas. The first construction began early on the morning of April 24, 1959, when brush and trees were cleared in the area which was to become the Center's main entrance.

The computer and switchboard rooms were occupied on April 28, 1960. By June and July of the same year, the remainder of Building 1 was completely occupied, although steam for operation of heating system and refrigeration compressors for air conditioning were provided by a temporary boiler outside the building. September 16, 1960, saw the full operation of Building 2.

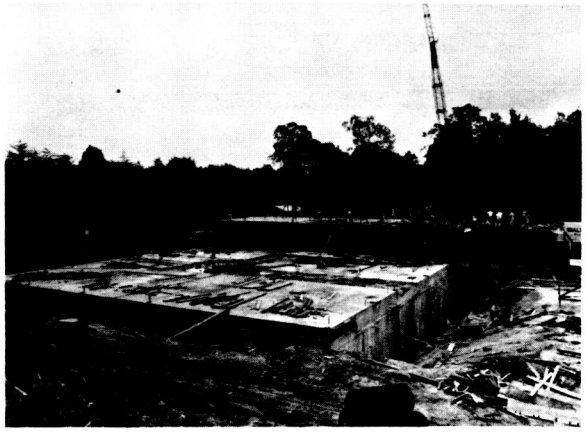
Humphreys and Harding, Inc., began construction of the Central Flight Control and Range Operations Building (Building 3) on September 21, 1959. Installation of computer equipment was completed on March 1, 1961, while other portions of the computer and communications area were occupied in November and December of the same year.

Building 4, housing service shops, central powerplant, refrigeration plant, cooling tower, emergency power generators, and office areas, was started on May 23, 1960, under contract with Norair Engineering Corporation. Parking lot and roads were also included under this con-



Location plan of Center, 1963 estimates.

The site for Building 1, June 1959.



Building 1 under construction, October 1959.

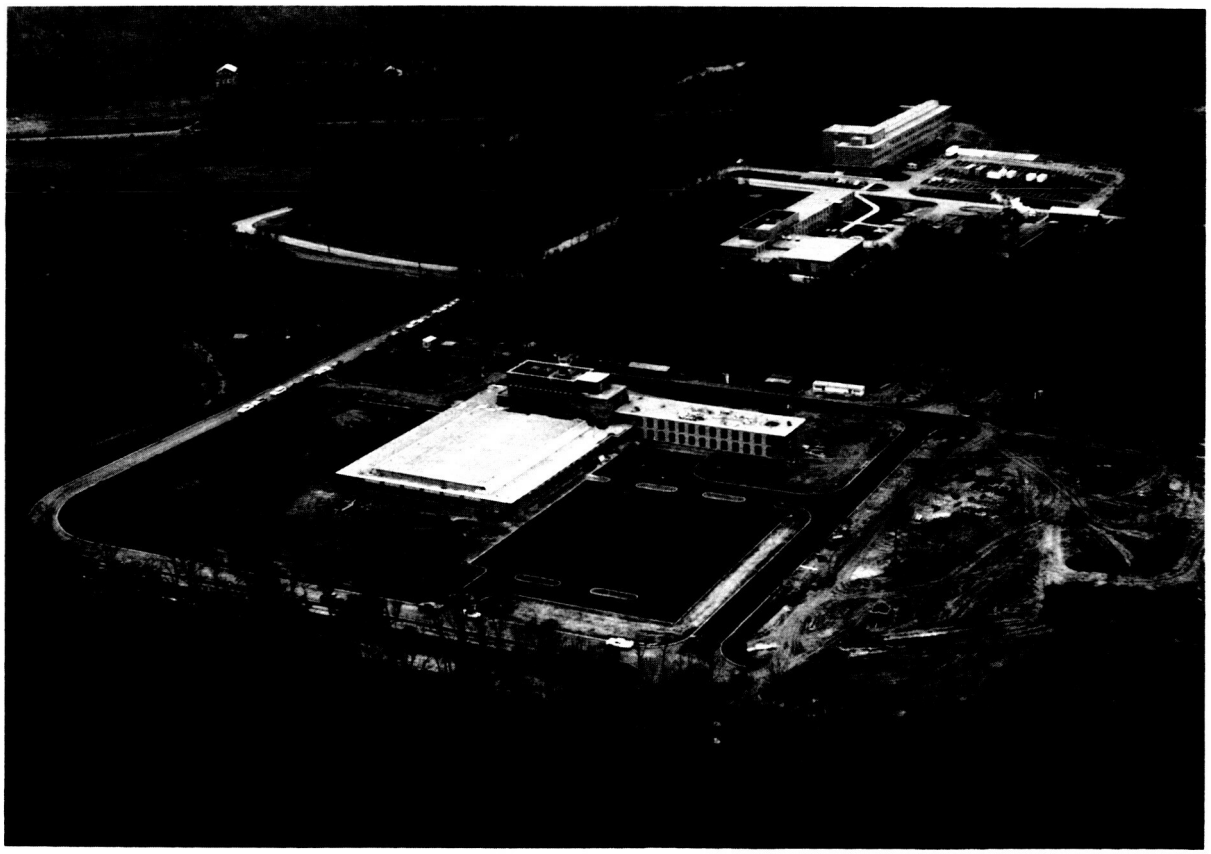
Building 1.

tract. Initial completion of steam service lines, temporary boiler, and service shops was accomplished in November while office space, parking lot, and boilers were placed in operation on December 20, 1960. Completion of construction and the refrigeration equipment installation were accomplished on May 29, 1961.

The Instrument Construction and Installation Laboratory, Building 5, under contract with Norair Engineering Corporation, was started on November 26, 1960. Initial completion phases of this structure accommodated many administrative and scientific personnel formerly housed in temporary quarters. In early 1962 it was necessary to modify the Machine Shop and upper floor areas to house this personnel pending completion of Buildings 6, 8, and 11. Building 5 was completed on March 20, 1962.

Arthur Venneri Co. was low bidder on a contract to build the Space Science Laboratory, Building 6. Construction was begun on November 19, 1960. By February 1962, the lower floors were completed and sections A and B were ready for occupancy. The remaining portion of the building required one additional month, and the staff took possession on March 2, 1962.

The contract for Buildings 7 and 10 went to United Engineers and Constructors, Inc., on

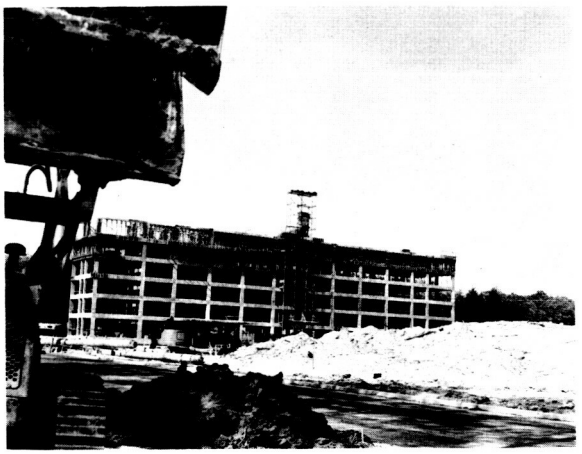


Aerial view of Buildings 1, 2, and 3.

January 31, 1961. Notice to proceed with the construction of Building 7 was given in May 1961; construction started May 22, 1961. Occupancy by the Test and Evaluation Division, formerly housed in Building 4 and in numerous trailers, began April 28 and was completed the next month.

Construction of Building 10 was started on October 19, 1961, by United Engineers and Constructors, Inc., with a scheduled contract completion date of September 1, 1962. Sufficient portions of the building, together with the overhead crane, were completed by March 2, 1962, to start installation of the Space Environmental Simulator and Dynamic Test Chambers by Minneapolis-Honeywell Corporation.

The Satellite Systems Building 8, under contract with Arthur Venneri Co., was begun on September 16, 1961, and was targeted for occupancy by Spring 1963. Featuring a 500-seat auditorium, it also included provisions for a presentation-type stage, multipurpose projection booth, and wide-range sound facilities. Building 8 was to house the Director, Associate Director, Assistant Directors, and supporting administrative services offices of the Center.



Building 8 under construction, July 1962.

Construction on Building 11, an Applied Sciences Laboratory, was begun by the Norair Engineering Corporation of Washington, D.C., on August 16, 1962. The estimated completion date was September 1963.

A contract for the construction of Building 12 was awarded to the Piracci Construction Company of Baltimore. This building, a Tracking and Telemetry Laboratory, will augment such facilities now in Building 3. Construction was begun on October 22, 1962, and the estimated completion date was November 1963. Each of the above buildings will have laboratory and office space for approximately 350 employees.

The assignment of space for the most effective administration of the Center continued to be a critical problem, and occupancy in many areas was on a temporary basis. This particularly applied to Buildings 1 and 5. Many of the administrative offices which eventually were scheduled to be located elsewhere at the Center were housed in rented space in the Jackson Building, Bladensburg, Md.; at Lawrence St., Bladensburg, Md; at Litton Industries, College Park, Md.; at Beltsville; and at the relatively nearby location: Colemont Building, Silver Spring, Md.

ORGANIZATIONAL GROWTH

A review of the organizational charts for 1959 to 1962 gives an indication of the Center's growth while, at the same time, adhering to its original concepts. As noted earlier, the manned satellite function shown in the first two charts was transferred from Goddard Space Flight Center to the Manned Spacecraft Center at Houston, Texas, on January 1, 1961.

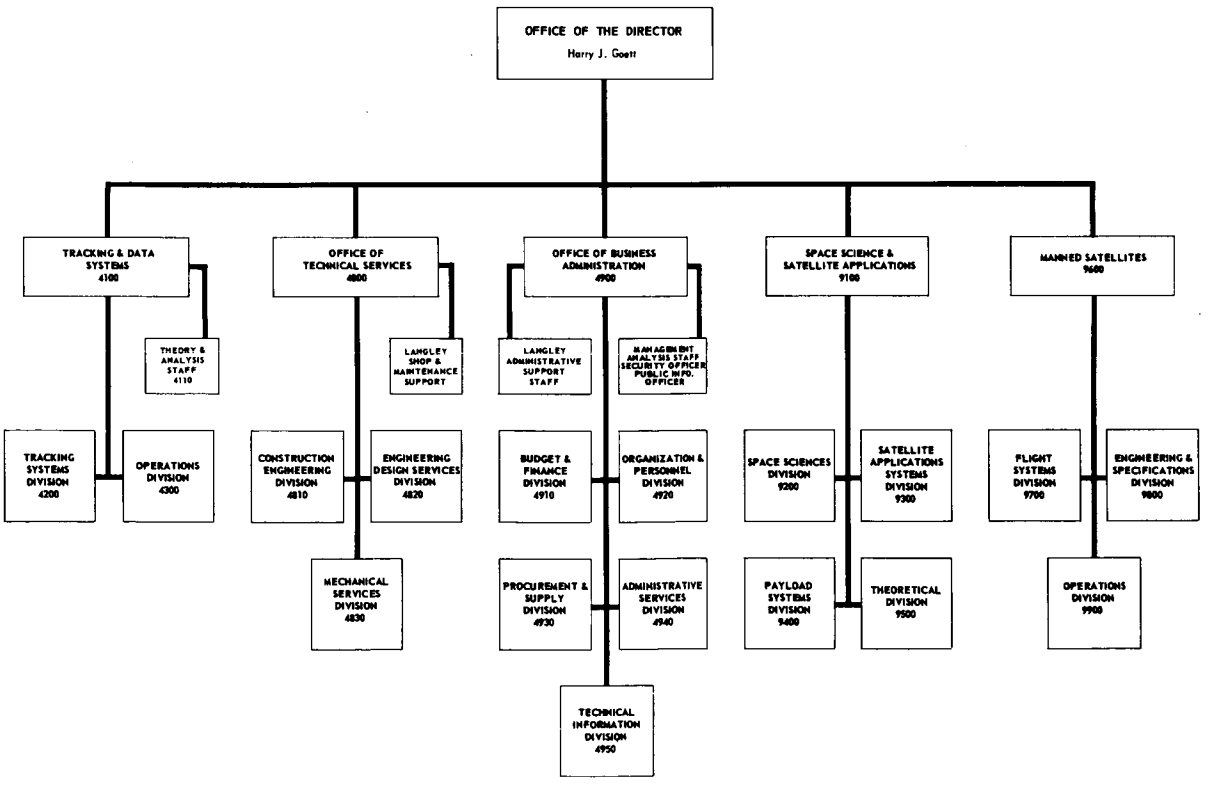
The four major elements: Administration (formerly Business Administration), Tracking and Data Systems, Space Science and Satellite Applications, and Technical Services remained basically the same but with further refinements. The Office of Technical Services expanded to include such divisions as Facilities Engineering, Test and Evaluation, and Fabrication instead of Construction Engineering, Engineering Design Services, and Mechanical Services.

The Office of Space Science and Satellite Applications, while retaining essentially the same functions, recognized the need for the creation of a separate division for aeronomy and meteorology. Also, the Institute for Space Studies in New York City was established first as a separate element of the Theoretical Division and then directly under the Assistant Director,

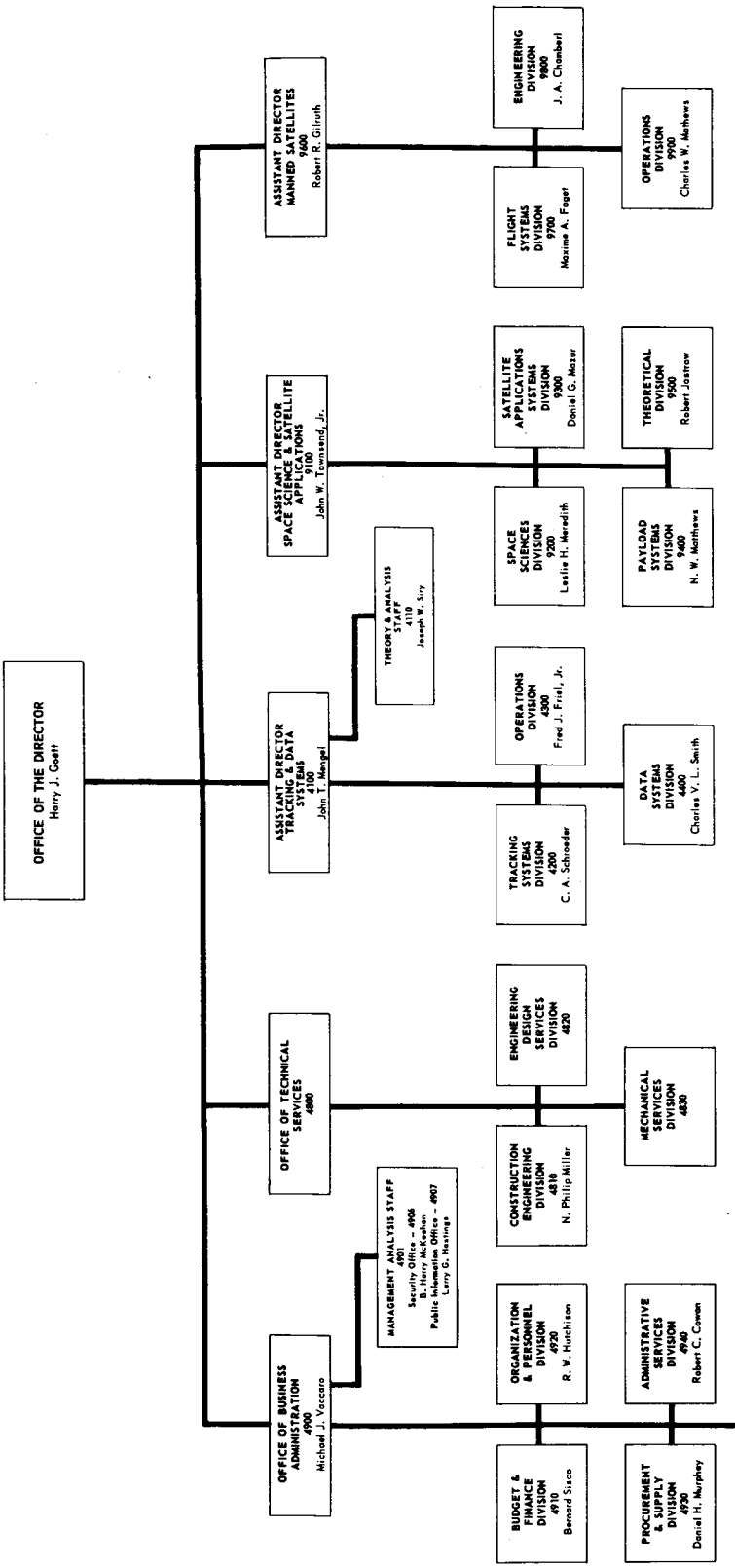
Occupancy by Directorate and Location, June 12, 1962

Building*	1	2	3	4	5	6	7	8	Jac	Law	CFO	Litton	ARC	Cole	Litton 2A	Cape	NYC
Dir. & Asst. Dir. OA—585:																	
84 Dir Asst Dir—OA	25	-----	-----	-----	41	-----	1	5	12	-----	-----	-----	-----	-----	-----	-----	-----
82 Fin Mgmt	12	-----	-----	-----	70	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
81 O & P	2	-----	-----	-----	79	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
57 Mgmt Ser	39	-----	-----	-----	18	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
219 P & S	16	-----	-----	-----	-----	-----	-----	-----	100	103	-----	-----	-----	-----	-----	-----	-----
62 TID	30	-----	-----	-----	32	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Office of Tech. Serv.—456:																	
2 Chief OTS	-----	-----	-----	-----	-----	-----	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
140 Fac Eng	-----	-----	-----	115	-----	-----	-----	-----	-----	-----	25	-----	-----	-----	-----	-----	-----
188 Test & Eval	-----	-----	-----	30	-----	-----	158	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
126 Fab Div	-----	4	-----	-----	113	5	4	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Track & Data Sys.—725:																	
17 Asst Dir	-----	-----	17	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
130 Track Sys	-----	-----	125	-----	-----	-----	-----	-----	-----	-----	-----	-----	5	-----	-----	-----	-----
116 OP & Sup	-----	-----	94	-----	-----	-----	22	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
219 Data Sys	-----	-----	219	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
164 Spa Data Acq	-----	-----	6	-----	-----	20	-----	-----	-----	-----	-----	138	-----	-----	-----	-----	-----
79 MSFS	-----	-----	19	-----	60	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Space Sci. & Sat. App.—1123:																	
11 Asst Dir	-----	-----	-----	-----	-----	11	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
284 Spa Sci	-----	213	-----	-----	-----	10	-----	-----	-----	-----	-----	-----	-----	12	49	-----	-----
185 Spa Sys & Proj	-----	-----	-----	-----	50	105	-----	-----	-----	-----	-----	-----	-----	-----	-----	30	-----
175 Aero & Mete	16	137	-----	-----	22	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
326 Spac Tech	-----	5	-----	16	-----	305	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
142 Theo	86	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	56
Incl. {84 NOS / 372 CONT}—2889	226	359	480	161	485	456	187	5	112	103	25	138	5	12	49	30	56

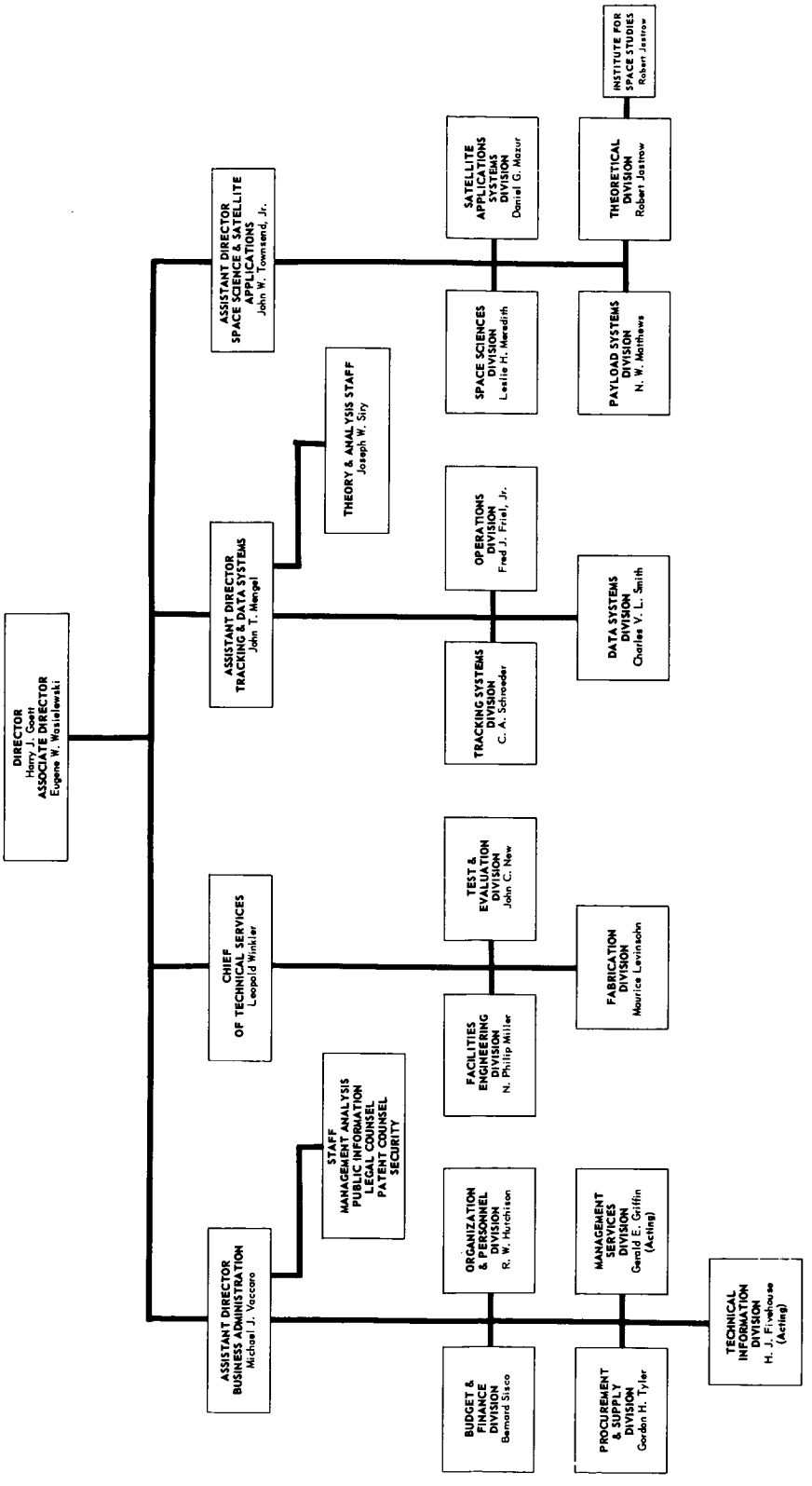
* Jac—Jackson St.
Law—Lawrence St.
CFO—Construction Field Office.
ARC—Agricultural Research Center
Cole—Colemont
Cape—Cape Canaveral
NYC—Institute for Space Studies, New York.



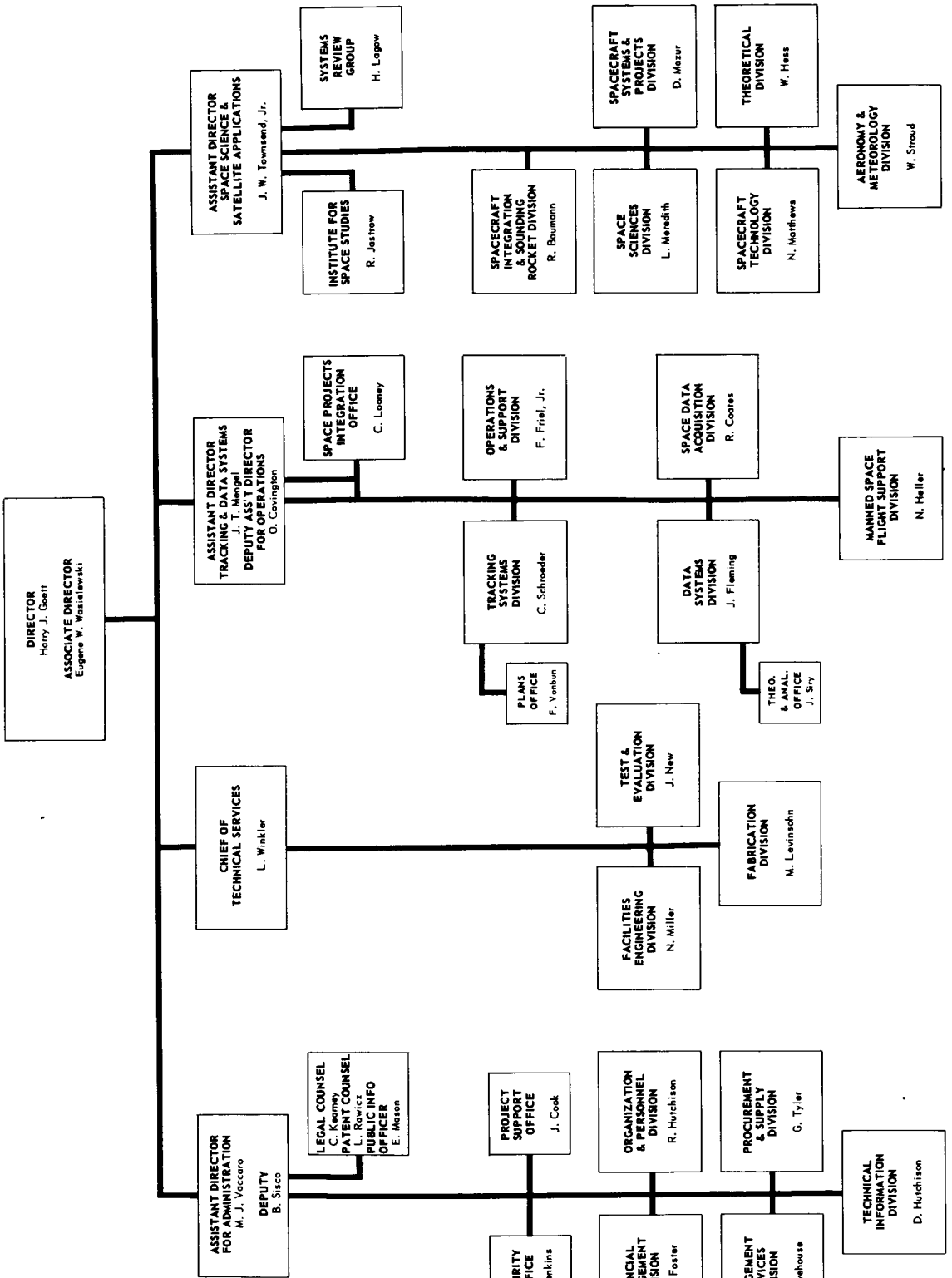
Organization chart, July 1959.



Organization chart, March 1960.



Organization chart, January 1961.



Organization chart, November 1962.

Goddard Space Flight Center Funding

(Exclusive of Research & Development program funds)

Year	Funding (in millions of dollars)			
	Salaries & Expenses	Construction & Equipment	Plant Support	Total
1959	2. 02	3. 87	0. 14	6. 03
1960	11. 40	14. 07	3. 56	29. 03
1961	16. 31	16. 76	4. 97	38. 04
1962	26. 68	11. 18	11. 47	49. 33

Advanced Research and Technology

Year	Funding (in millions of dollars)
1959	0
1960	0
1961	0
1962	2. 78

Research and Development Program Funding for Major GSFC Missions

Year	Funding (in millions of dollars)						
	Sounding Rockets	Satellites			Tracking and Data Acquisition	Delta Launch Vehicle	Total
		Scientific	Meteorological	Communications			
1959	3. 56	21. 31	0. 99	3. 57	3. 10	12. 93	45. 46
1960	9. 68	20. 24	7. 93	3. 05	16. 19	12. 48	69. 57
1961	8. 25	35. 14	17. 50	31. 15	29. 65	9. 58	131. 27
1962	7. 29	67. 64	26. 97	21. 42	45. 13	0. 70	169. 15

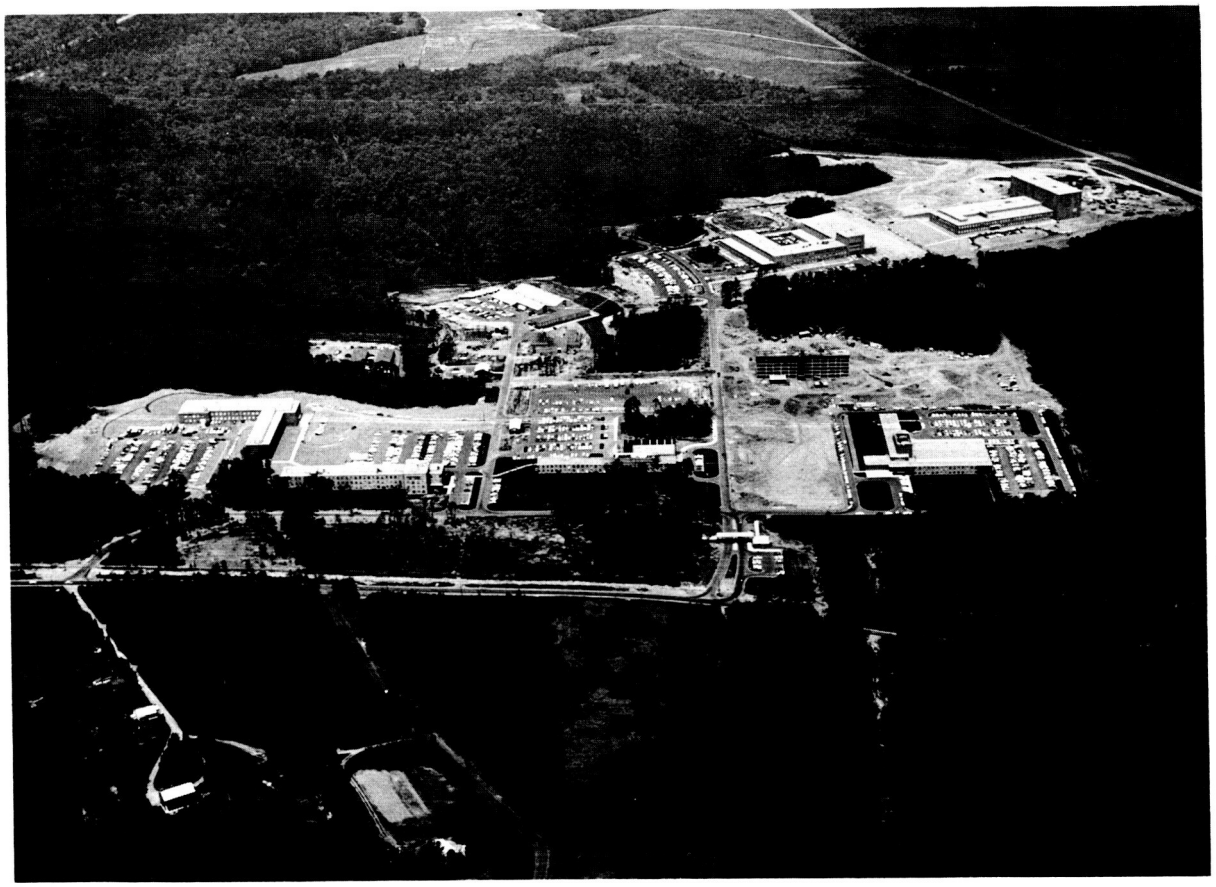
Office of Space Science and Satellite Applications.

The responsibilities of the Office of Tracking and Data Systems grew to the point where the original breakdown with a Theory and Analysis Staff, a Tracking Systems Divisions, and an Operations Division no longer was adequate. It expanded to include a Space Projects Integration Office, an Operations and Support Division, a Tracking Systems Division (with a Plans Office), a Space Data Acquisition Division, a Data Systems Division (with a Theory and Analysis Office) and a Manned Space Flight Support Division.

PROJECT MANAGEMENT

The Goddard Space Flight Center was organized along functional lines, which were considered best from the standpoint of developing and maintaining a strong competence in the scientific and technical disciplines. Under this concept a *project manager* whose responsibility was to oversee all facets of a major project was designated. He acted as the agent of management to assure that all resources, both in-house and outside house, were effectively used to serve the needs of the project. He met this responsibility by way of the authority of the functional *line supervisors.* For such a system to work required, in the first place, effective communications with line supervisors and, secondly, the rapid and direct access of the project manager to top management in the event that problems arose from conflicts between the needs of the various projects and the more general discipline activities. To keep his finger on the Center's pulse, the Director and key staff elements received "Weekly Progress Reports," in which project managers discussed progress and problems. At periodic intervals, project managers made oral presentations to the top management staff at weekly staff conferences of the Director.

Virtually every segment of the Goddard organization was organized to support this concept.



Aerial view of Goddard Space Flight Center, June 1962.

WORKING WITH AMERICAN INDUSTRY

Goddard's varied missions required the services and support of many elements of the American industrial community. By the end of 1962, more than 85 percent of the Center's efforts in research and development areas were contracted for with outside concerns including industrial, research, and educational establishments. At the same time the Center followed the policy of retaining a sufficient number of projects to retain adequate in-house capability among its own staff in order to supervise its programs effectively.

To keep the industrial community abreast of Goddard's needs and anticipated projects, the Center held "Industry Conferences" and participated in NASA Headquarters-sponsored seminars held in Washington, D.C., and key cities throughout the United States.

FINANCIAL MANAGEMENT

The Financial Management Division participated in translating the Goddard Space Flight Center requirements into a financial plan, and provided financial guidance to the Center's top staff and financial support to project managers.

It administered the budget and provided guidance to all elements in coordinating operating plans with cost estimates. It also developed and provided effective accounting systems, processed all machine accounting transactions and processed statistical and other data on financial matters.

It planned and executed financial analysis for scientific satellite projects and kept all concerned fully and currently advised of cost trends.

The tables shown on p. 39 illustrate the ever-increasing fiscal responsibilities of this Center.

PROCUREMENT

The procurement problems were complicated by the fact that, in many instances, procurement action had to be taken to acquire items never before manufactured, never before on the drawing board. To this was added the fact that sometimes materials of a rare or "exotic" nature having limited availability were required. This called for extensive knowledge of supply sources, capabilities, and past delivery performance of industrial firms and other vendors.

Many procurement requests had to be processed—requiring detailed monitoring. Combined with these factors was the necessity to conform to detailed legislative and regulatory procedures as well as to sound business practices.

Contracting with industry on a multimillion dollar scale required the Center to seek the highest quality of American scientific and industrial skill, as well as the best capabilities of other Government laboratories.

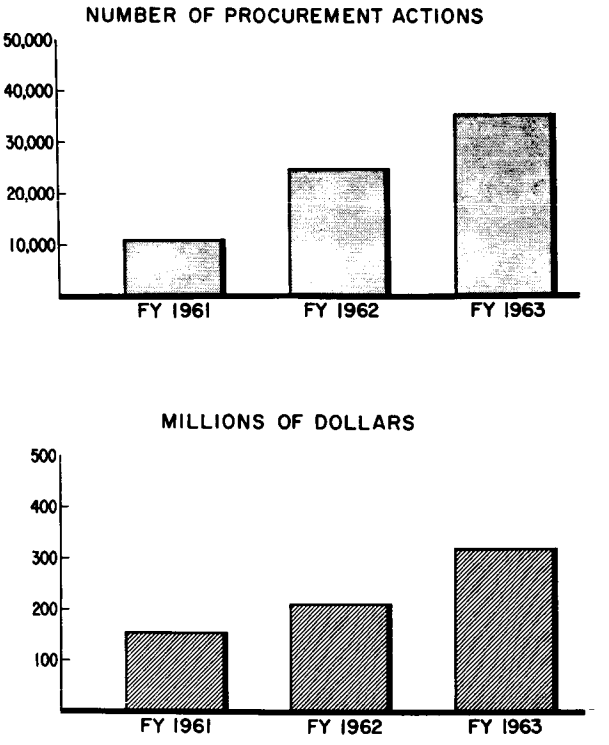
Each experiment in space was characterized by a high degree of attention to individual design and assembly. Even in a series of projects having the same general purpose, the payload packages varied according to the experiments they conducted. Seldom, if ever, were any two flights identical.

FABRICATION AND TESTING

A scientific satellite is not a mass-produced item but usually a one-of-a-kind spacecraft which contains delicate scientific and electronic equipment. It requires the best engineering talents to build and test these space-borne laboratories.

Manufacture of these space vehicles was accomplished either "in-house" by the Center's staff of skilled fabricators or under contract with American industry—or through a combination of both. The Center's fabrication staff was composed of a small but highly specialized team of engineers and technicians skilled in machining, forming, optics, electronics, satellite assembly, et cetera.

Once fabricated, each spacecraft first had to survive environmental stresses due to ground



Procurement actions and expenditures.

handling and launching. It finally had to operate effectively in space for its expected lifetime. The task was not a simple one, since these spacecraft contained equipment heretofore used only under the ideal environment of a laboratory. In space, these instruments had to operate reliably at great distances and under conditions where they were to be subjected to solar radiation, space vacuum, extreme coldness, radiation belts, and solar flares. And, unlike a laboratory, there could be no experienced experimenter in attendance, making adjustments and taking readings.

A complex, labeled Goddard's Spacecraft Test Facility, served as a large-scale laboratory to test Goddard-developed spacecraft and probes. Here a satellite was exposed to man-made conditions of extreme temperature, humidity, shock, vibration, structural loadings, and various combinations to assure that Goddard developed projects could take the punishment which they were to face on their orbital missions.

These facilities were capable of handling one 4000-pound payload, plus two 1000-pound loads

SUMMARY REPORT OF PROCUREMENT ACTIONS

For January 1, 1960, thru June 30, 1960

FROM: Goddard Space Flight Center*

TO: NASA Headquarters

NUMBER AND DOLLAR VALUE OF CONTRACT TRANSACTIONS

ACTIONS OVER $2500	Govt. Agency		Small business		Big business		Educational et al	
	No.	$ Value	No.	$ value	No.	$ value	No.	$ value
1. RESEARCH & DEVELOPMENT								
a. Negotiated			50	1,502,222	69	18,675,289	2	920,787
b. Interdepartmental	102	29,067,246						
Total	102	29,067,246	50	1,502,222	69	18,675,289	2	920,787
2. CONSTRUCTION								
a. Advertised			7	482,618	4	1,558,743		
b. Negotiated			11	199,950	4	94,551		
c. Interdepartmental	9	2,103,340						
Total	9	2,103,340	18	382,568	8	1,653,294	-	-
3. SUPPLY								
a. Advertised			9	202,392	7	54,839		
b. Negotiated			17	295,136	20	473,460		
c. Interdepartmental	67	4,585,142						
d. GSA schedule			4	19,486	11	60,844		
Total	67	4,585,142	30	517,014	38	589,143		
4. TOTAL ACTIONS OVER $2500	178	36,147,504	94	2,401,804	115	20,917,726	2	920,787
5. ALL ACTIONS NOT EXCEEDING $2500	75	40,311	856	343,607	450	259,956		

NASA Form 274 rev. (Jan. 1959)

*This Report includes Space Task Group, Langley

YEARLY REPORT OF PROCUREMENT ACTIONS

NASA Installation GODDARD SPACE FLIGHT CENTER — FISCAL YEAR 1961

PART A: PROCUREMENT ACTIONS BY NASA APPROPRIATION

Category	Total		Research & Development		Construction & Equipment		Salaries & Expenses	
(a)	No. (b)	$ Value (c)	No. (d)	$ Value (e)	No. (f)	$ Value (g)	No. (h)	$ Value (i)
1. TOTAL	10723	188,420,999	10426	165,376,920	248	21,921,420	51	1,122,659
2. INTERGOVERNMENTAL	613	42,059,736	579	36,010,924	27	6,021,096	7	27,710
3. NONPROFIT INSTITUTION OR ORGANIZATION	176	2,697,931	173	2,022,181	2	675,000	1	750
4. SMALL BUSINESS - TOTAL	6482	14,466,277	6401	11,112,542	73	3,297,826	8	55,909
a. Advertised	594	1,735,627	554	581,835	40	1,153,792	-	-
b. Negotiated Competitive	2432	5,442,402	2417	3,986,711	15	1,630,696	-	-
c. Negotiated Non-Competitive	3369	7,158,330	3271	5,144,613	18	512,808	8	55,909
d. Government Schedule	159	129,918	159	129,918	-	-	-	-
5. LARGE BUSINESS - TOTAL	3432	129,197,061	3273	116,231,723	146	11,927,498	33	1,038,290
a. Advertised	169	5,591,609	77	399,565	92	5,192,044	-	-
b. Negotiated Competitive	887	64,284,021	875	61,988,687	12	2,295,334	-	-
c. Negotiated Non-Competitive	1889	57,942,090	1843	53,427,951	40	4,448,034	6	76,105
d. Government Schedule	507	1,379,341	559	415,070	2	2,086	27	962,185

PART B: NEGOTIATED PROCUREMENT ACTIONS

Negotiation Authority 10 U.S.C.	Number	$ Value	Negotiation Authority 10 U.S.C.	Number	$ Value
6. TOTAL	8681	137,524,774	2304(a) (9)		
2304(a) (1)	509	9,523,642	(10)	210	14,578,340
(2)			(11)	166	101,939,320
(3)	7738	3,735,543	(12)		
(4)	12	211,012	(13)		
(5)	14	2,436,764	(14)	29	4,725,153
(6)	3	375,000	(15)		
(7)			(16)		
(8)			(17)		

NASA FORM 508 (JUNE 1960)

YEARLY REPORT OF PROCUREMENT ACTIONS

NASA Installation GODDARD SPACE FLIGHT CENTER FISCAL YEAR 1962

PART A: PROCUREMENT ACTIONS BY NASA APPROPRIATION

Category	Total		Research & Development		Construction & Equipment		Salaries & Expenses	
(a)	No. (b)	$ Value (c)	No. (d)	$ Value (e)	No. (f)	$ Value (g)	No. (h)	$ Value (i)
1. TOTAL	20717	209,292,154	20432	188,234,691	205	19,824,349	80	1,233,114
2. INTERGOVERNMENTAL	616	5,752,844	612	5,746,868	1	1,736	3	4,240
3. NONPROFIT INSTITUTION OR ORGANIZATION	188	13,209,413	183	12,456,011	2	744,980	3	8,422
4. SMALL BUSINESS - TOTAL	14436	23,299,070	14367	22,274,592	50	835,665	19	118,813
a. Advertised	252	3,194,931	232	2,909,887	17	244,332	3	40,712
b. Negotiated Competitive	3374	5,721,710	3362	5,645,711	11	75,201	1	798
c. Negotiated Non-Competitive	10370	13,676,111	10335	13,143,676	22	516,132	13	16,303
d. Government Schedule	440	636,318	438	575,318			2	61,000
5. LARGE BUSINESS - TOTAL	5477	167,100,827	5270	147,757,220	152	18,241,968	55	1,101,639
a. Advertised	517	7,039,954	428	4,626,221	88	2,410,733	1	3,000
b. Negotiated Competitive	1336	73,554,241	1308	66,829,131	17	6,401,550	11	323,560
c. Negotiated Non-Competitive	2874	82,281,111	2806	75,325,984	41	6,504,601	27	450,526
d. Government Schedule	750	4,225,521	728	975,884	6	2,925,084	16	324,553

PART B: NEGOTIATED PROCUREMENT ACTIONS

Negotiation Authority 10 U.S.C.	Number	$ Value	Negotiation Authority 10 U.S.C.	Number	$ Value
6. TOTAL	18,142	188,442,554	2304(a) (9)		
2304(a) (1)	736	15,934,895	(10)	853	42,056,080
(2)	12	625,380	(11)	235	103,911,638
(3)	16,192	7,683,152	(12)		
(4)	18	291,477	(13)		
(5)	59	8,897,255	(14)	16	4,144,396
(6)	20	4,895,388	(15)		
(7)			(16)		
(8)			(17)	17	2,893

NASA FORM 508 (JUNE 1960)

QUARTERLY REPORT OF PROCUREMENT ACTIONS

(Use reverse for remarks)

FOR THE First Half FY 1963

INCLUDES NASA FORM 507 — REPORTS NOS. — THRU.

TO: Procurement and Supply Division, Headquarters, NASA

FROM: *(NASA Installation)* Goddard

July 1 - Dec. 31-62

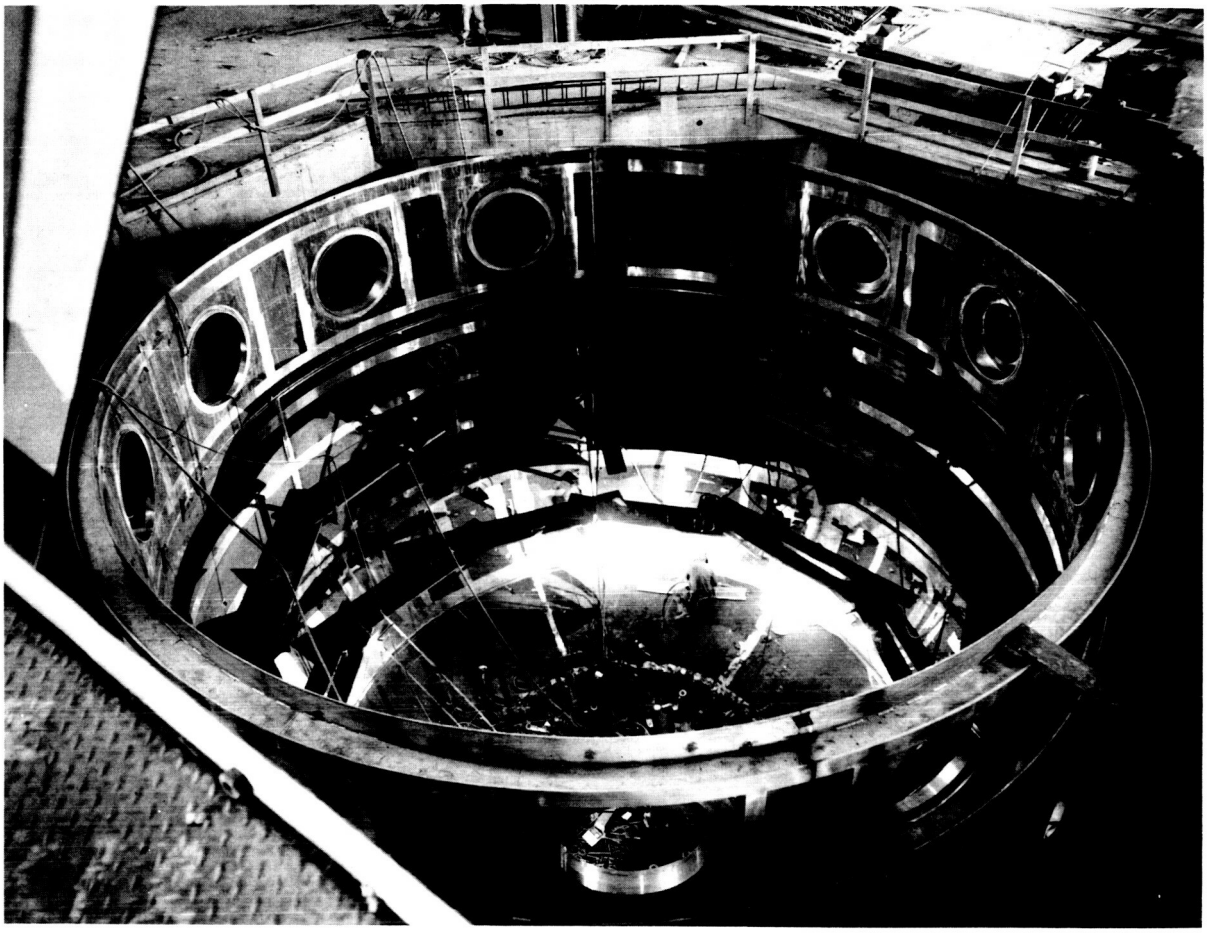
PART A - PROCUREMENT ACTIONS BY NASA APPROPRIATION

CATEGORY (a)	TOTAL NO. (b)	TOTAL $ VALUE (c)	RESEARCH DEVELOPMENT AND OPERATIONS NO. (d)	RESEARCH DEVELOPMENT AND OPERATIONS $ VALUE (e)	CONSTRUCTION OF FACILITIES NO. (f)	CONSTRUCTION OF FACILITIES $ VALUE (g)
1. TOTAL *(Lines 2 thru 7)*	12258	125,113,829	12196	115,503,346	62	9,610,483
2. INTRAGOVERNMENTAL	282	6,643,523	281	3,793,523	1	2,850,000
3. LARGE BUSINESS - TOTAL	3383	94,996,622	3347	88,771,327	36	6,225,295
a. Advertised	85	4,115,895	73	693,778	12	3,422,117
b. Negotiated Competitive	845	53,076,992	833	53,053,665	12	23,327
c. Negotiated Noncompetitive	2453	37,803,735	2441	35,023,884	12	2,779,851
4. SMALL BUSINESS - TOTAL	8531	17,146,612	8508	16,804,424	23	342,188
a. Advertised	129	4,052,466	120	3,856,270	9	196,196
b. Negotiated Competitive	1801	2,056,806	1798	1,945,020	3	111,786
c. Negotiated Noncompetitive	6601	11,037,340	6590	11,003,134	11	34,206
5. UNIVERSITIES	49	4,823,379	48	4,773,379	1	50,000
6. OTHER NONPROFIT INSTITUTIONS	3	15,093	3	15,093	--	------
7. OUTSIDE U.S. & POSSESSIONS	10	1,488,600	9	1,345,600	1	143,000
8. SMALL BUSINESS SET ASIDES - TOTAL *(included in line 4)*	15	457,240	14	419,041	1	38,199
a. Individual Set Asides	15	457,240	14	419,041	1	38,199
b. Class Set Asides						

PART B - NEGOTIATED PROCUREMENT ACTIONS

NEGOTIATION AUTHORITY 10 U.S.C.	NO.	$ VALUE	NEGOTIATION AUTHORITY 10 U.S.C.	NO.	$ VALUE
9. TOTAL	11762	110,301,945	2304(a) (9)	---	--------
2304(a) (1)	650	6,305,512	(10)	866	16,383,673
(2)	64	2,071,703	(11)	115	63,452,807
(3)	9216	5,393,763	(12)	--	-------
(4)	15	244,978	(13)	--	-------
(5)	43	4,447,279	(14)	4	2,137,064
(6)	16	1,864,700	(15)	--	-------
(7)	--	-------	(16)	--	-------
(8)	--	-------	(17)	773	8,000,466

NASA FORM 508 (REV. OCT 62) PREVIOUS EDITIONS ARE OBSOLETE. GPO 935427



The space environment simulator under construction.

simultaneously, measuring up to 25 feet. Two major items in the Center's Spacecraft Test Facility were a dynamic test chamber and a space environment simulator. These chambers simulated some of the forces converging on a spacecraft from initial ground handling through launch and flight.

The dynamic test chamber consisted of a stainless-steel structure 33½ feet in diameter and 58 feet high. Powerful mechanical pumps reduced inside pressure to 0.1 mm mercury. Here dynamic balancing, solar paddle erection, spacecraft orienting, etc. could be tested.

In the laboratory's space environment simulator, a spacecraft could be exposed to simulated conditions of cold outer space, extreme vacuum, and solar radiation.

A review of scientific satellite failures that have been detected by means of environmental test programs was made for the calendar year 1962. This review of 114 failures, while not exhaustive, is believed to be representative of results that can be achieved. Five satellites were chosen for this review, all of which were launched and successfully performed in space during 1962. These satellites were chosen to represent several factors that might influence their complexity. For example, weights varied from less than 100 to over 300 pounds, and three launch vehicles were represented. The scientific disciplines represented by the on-board experiments covered electron density; galactic noise; corpuscular, solar, and cosmic radiation; magnetic fields; ionospheric relations; and communication experiments. The telemetry systems were typically pulse-frequency modulated, although one system included traveling wave tubes. Only one of the systems used batteries

exclusively; the other four included solar cells for power. The satellites reviewed include those developed by NASA, by industry, and through international cooperation. They all, however, were tested under the same philosophy expressed herein.

Detailed statistics are found in the tables below. Some salient observations were that the ratio of electrical to mechanical failures was 4:1 (80 vs. 20 percent). The mechanical problems were chiefly concerned with antenna designs, subsystem mounting, and local resonances. Stronger and stiffer designs, together with damping (often by potting), were general solutions to these problems. Often electrical problems were erratic and spurious, requiring much troubleshooting. Solid-state components often were found to be faulty. Local overheating was often corrected by providing improved heat sinks and heat conduction paths. The failure distribution seems reasonably consistent between the satellites. Nearly one-half of the failures reviewed occurred during the thermal-vacuum test, which stimulated space conditions. However, nearly one-sixth of the failures occurred during checkout, and about one-third during vibration. One observation made from these data was the importance of completing the entire system and checking it out early in the project life. One-sixth of the errors noted were primarily indicative of the interaction of subsystems and the many interface problems. Cabling and connectors were particular offenders

Failure Distribution by Spacecraft

Spacecraft	Weight (lb)	Vehicle	Failures During Test					
			Electrical		Mechanical		Total	
			No.	%	No.	%	No.	%
A	94	Scout	10	71	4	29	14	12
B	170	Delta	15	83	3	17	18	16
C	86	Delta	18	78	5	22	23	20
D	150	Delta	42	86	7	14	49	43
E	310	Thor-Agena	6	60	4	40	10	9
Total			91	80	23	20	114	100

Failure Distribution by Test Condition

Failure Category	Failure During Test*														
	Electrical							Mechanical						Total	
	A	B	C	D	E	Total		A	B	C	D	E	Total		
						No.	%						No.	%	No.	%
Checkout	----	2	3	5	2	12	13	----	----	1	4	1	6	26	18	16
Vibration	7	5	3	4	1	20	22	4	3	3	1	3	14	61	34	30
Temperature	----	1	1	----	1	3	3	----	----	----	----	----	----	----	3	3
Vacuum	----	1	3	1	----	5	5	----	----	----	----	----	----	----	5	4
Thermal-vacuum	3	6	8	32	2	51	56	----	----	1	2	----	3	13	54	47
Total	10	15	18	42	6	91	100	4	3	5	7	4	23	100	114	100

*Test conditions for spacecraft A, B, C, D, and E in table above.

Drs. Robert Jastrow, Jackson Herring, Hong Yee Chiu, and Albert Arking of the Institute for Space Studies.

at this stage of checkout. The primary item to note again was that each of these failures was detected, corrected, tested, and evaluated. The final result in space was a successful satellite.*

INSTITUTE FOR SPACE STUDIES

To provide a point of contact between the national space program and an area rich in universities and scientific talent, the Institute for Space Studies was established in New York City in May 1961 as a part of the Goddard Space Flight Center.

The Institute's primary mission was to assist in the analysis and interpretation of NASA space probes. It was concerned with basic theoretical research in a broad variety of fields, including the structure of the earth, the moon, and other planetary bodies in the solar system; the atmospheres of the earth and other planets; the origin and evolution of the solar system; the properties of interplanetary plasma; sun-earth relations; and the structure and evolution of stars.

The second major mission of the Institute was to arouse the interest of university scientists and students in the space program and to enlist their participation in some of the theoretical problems of space research. With its location in New York, the Institute had a unique opportunity for direct contact with the metropolitan university community. In its first year it developed associations with Princeton University, Yale University, Columbia University, New York University, the City University of New York, and Brooklyn Polytechnic Institute.

The Institute was originally designated as a New York office of the Theoretical Division of the Goddard Space Flight Center. Dr. Robert

*New, J. C., "Scientific Satellites and the Space Environment," NASA Technical Note D–1340, June 1962.
Boeckel, J. H., "The Purposes of Environmental Testing for Scientific Satellites, "NASA Technical Note D–1900, 1963.
Timmins, A. R., and Rosette, K. L., "Experience in Thermal-Vacuum Testing Earth Satellites at Goddard Space Flight Center," NASA Technical Note D–1748, 1963.

Jastrow was named Director and also continued as Chief of the Theoretical Division. In July 1962, the Institute was separated from the GSFC Theoretical Division as noted earlier in this chapter.

GODDARD LAUNCH TEAMS

Much of the success of the Goddard satellite program was due to the efforts of its launch teams, organized under the Directorate for Space Science and Satellite Applications, with personnel at both the Atlantic and Pacific Missile Ranges (AMR and PMR). The AMR team provided the management and technical direction of the field efforts involving the successful Delta launch vehicle. Under the Field Projects Branch, Goddard scientists and engineers closely supervised, monitored, and directed the launch vehicle preparations, launch operations, and coordination for spacecraft checkout. A similar team at PMR was responsible for the field integration of the spacecraft and launch vehicle, and for coordinating and directing mission operations originating from PMR.

Chapter 5

TRACKING, DATA ACQUISITION, AND DATA REDUCTION

Historically, the first functional network to be constructed for satellite tracking was the *Minitrack* network. This network grew directly out of arrangements originally made by the United States with agencies abroad as part of the program for the International Geophysical Year. Among the overseas stations tied in with the satellite tracking network were Antigua, West Indies Federation; Quito, Ecuador; Lima, Peru; Antofagasta and Santiago, Chile; Woomera, Australia; and Esselen Park, Union of South Africa. These countries, in a program originally established in 1957 by the U.S. Naval Research Laboratory in cooperation with other agencies here and abroad, were all part of the Minitrack telemetry system.

On January 10, 1959, representatives of NASA and DOD met to coordinate the separate requirements of the two agencies, and arrived at an agreement for a "National Program To Meet Satellite and Space Vehicle Tracking and Surveillance Requirements for FY 1959 and FY 1960." The agreement, signed by Secretary of Defense McElroy and NASA Administrator Glennan, established respective responsibilities, mutual use of tracking data wherever possible, and led to the formation of a continuing NASA–DOD Space Flight Tracking Resources Committee.

The basic responsibilities of the network included: tracking, orbit computation, data acquisition (environmental and scientific telemetry), and data reduction.

The network consisted of three major functional parts. The first, *Minitrack Net*, has been used to track all U.S. satellites containing a suitable beacon since the beginning of the programs in 1957 and 1958.

MINITRACK NET

The Minitrack network comprised an organization of fixed ground stations, located throughout the world, to provide a means of precision tracking, command, and telemetry of satellites and space probes together with a communications system to transmit this information to a computing facility.

A large percentage of the original stations are located along the 75th meridian to intercept satellite orbits with inclinations of less than 45 degrees. New stations were added in higher latitudes to cope with more nearly polar orbits. Furthermore, ten of the stations were supplemented with additional antennas aligned specifically for polar orbit. (As of December 1962, the Minitrack system included the following stations: Blossom Point, Md.; Fort Myers, Fla.; Quito, Ecuador; Lima, Peru; Antofagasta, Chile; Santiago, Chile; Woomera, Australia; Esselen Park, South Africa; Goldstone, Calif.; St. Johns, Newfoundland; East Grand Forks, Minn.; Fairbanks, Alaska; and Winkfield, England.)

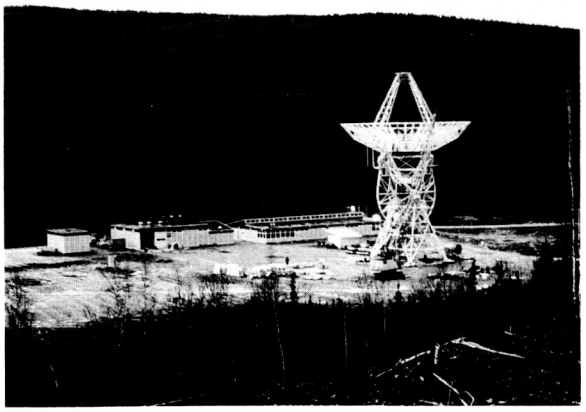
The prime Minitrack satellite tracking system consisted of radio interferometers* operating in conjunction with a transmitting beacon in the payload itself. Since the establishment of the network, certain enhancements have been added to the original station equipment to provide tracking capability by optical and Doppler means as well. While the original tracking equipment operated on or near 108 megacycles (Mc) (the frequency assigned for IGY activities), additional equipment, tunable over the 136–137 Mc region, has been provided.

WIDEBAND DATA ACQUISITION NET

Many of the satellites to be launched by NASA use very wide bandwidths for transmission of data from the satellite to the ground stations.

Since the receiver and sky noise in the telemetry link is proportional to the bandwidth used for reception, either a very high transmitter power or a very high antenna gain, or both, must be used for a wideband telemetry link in order to achieve good signal-to-noise ratios. Since transmitter powers are restricted for technical reasons, it became necessary to develop very high gain antennas at the ground stations for receiving the wideband telemetry signals. The antenna that best satisfies the requirements for high gain and multiple frequency operation is a parabolic antenna 85 feet in diameter.

The first satellite to require a large data acquisition facility for wide bandwidth reception will be Project Nimbus, which will be taking television pictures of the earth cloud cover. Nimbus is one of the satellites that will have a polar orbit. Consequently, the first station for wideband data acquisition was constructed on Gilmore Creek, 12 miles north of Fairbanks, Alaska; it was completed in May 1962. A contract was awarded the University of Alaska for operation of the station, which will be able to provide coverage for 70 percent of the passes of a satellite in a polar orbit. A contract for construction of a second station to be located near Rosman, North Carolina, was placed in July 1962; this station will pick up an additional 20 percent of the passes of a polar satellite. Thus, these two stations form a network which will provide coverage of 90 percent of the orbit of a satellite with a very high inclination.



Fairbanks, Alaska, Tracking Station.

*The radio interferometer measures two of the three direction cosines of a line from the center of the station to a satellite as a function of time while the satellite passes through the beam pattern of the receiving antennas. The third direction cosine is thus defined, and the angular position of the satellite is determined. From a series of independent angle measurements from various ground stations, satellite orbital elements may be computed.

Phase comparison techniques are used to measure the differences in arrival time of the wavefront of a distant point source at pairs of receiving antennas separated by known distances in wavelengths of the transmitted frequency. Measurement of this radio path difference is accomplished by a comparison of the phase angle of the signal received at one antenna to that received at another.

The antennas are aligned along baselines in the east–west and north–south directions. Since the phase measurement system is capable of indicating phase difference to a small fraction of a wavelength, two pairs of antennas are aligned along orthogonal baselines many multiples of a wavelength long to obtain good angular resolution. These are termed *fine* antennas. As a radio source passes through the antenna pattern, the relative phase will cycle from 0 to 360 degrees for each wavelength added to the radio path difference. Since the phase meters repeat their readings every 360 electrical degrees, a number of different space angles will produce identical phase readings during a satellite transit. This ambiguity is resolved by employing several progressively shorter baselines, which produce fewer integral numbers of wavelength change as the radio source passed through the antenna beam. These are termed *medium* and *coarse* antennas. Ambiguity antenna information determines the number of full wavelengths to be added to the relative phase angle measured at the fine antennas to define a data point.

The main antenna for the Alaskan station is an 85-foot-diameter paraboloid of revolution with a focal length of 36 feet. The surface consists of double-curved aluminum sheet panels. The surface is separate from the reflector structure so that it can be independently adjusted. The antenna reflector is mounted on an X–Y type mount designed specifically for tracking satellites.

The antenna is capable of tracking at rates from 0 to 3 degrees/second, with accelerations up to 5 degrees/sec^2. The pointing accuracy is ± 2 minutes of arc. The antenna has six operational modes: It will automatically track on a satellite signal; it can be driven by a teletype drive-tape input; it can be manually operated; it can be slaved to an acquisition antenna; or it can be operated in various search modes for initial acquisition.

TRACKING PROJECT MERCURY

Project Mercury was organized on October 7, 1958, to:

1. Place a manned space capsule into orbit around the earth
2. Investigate man's reactions to, and capabilities in, this environment
3. Recover both the capsule and the pilot safely

The Mercury program was conceived as a step-by-step development of a space-vehicle system and supporting ground system which would maximize the safety of the astronaut.

For the Project Mercury operations, Goddard operated a worldwide tracking network, which was constructed by private contractors and spans three oceans and three continents. The establishment of these tracking sites, insofar as location and equipment configuration, was prescribed by the character of the on-board electronics systems and existing facilities throughout the world, which were used to the maximum extent possible. This maximum utilization of existing facilities was mandatory in order that the rapid pace set for the project would not outstrip the development of the ground tracking system.

Since the major requirement was one of safety of flight, a highly reliable command system for backup of the functions of the astronaut by ground command was installed at strategic points around the earth. This requirement also made it mandatory that the onboard spacecraft systems be carefully monitored during all phases of the flight; this was accomplished by providing real-time telemetry display data at the sites.

Goddard Space Flight Center (GSFC) was the focal point for radar tracking, where real-time radar data were received from the sites. Two IBM 7090 computers provided launch and orbital computing during the flight; real-time display data were then transmitted to the Mercury Control Center at GSFC.

An air/ground communications system was established together with remote site-to-control center voice and teletype communications to maintain contact with the astronaut during all phases of the flight.

A special facility for testing and evaluation was established at Wallops Island, Va. Here, a typical site was constructed early in the phases of equipment procurement to evaluate the performance of the systems, determine the interface problems, develop detailed equipment testing procedures; establish calibration techniques and equipment to be utilized, and perform early training exercises. This proving ground for equipment was invaluable in providing a rapid evaluation of contractor developed equipment and testing procedures. Here also the criteria were established for ultimate acceptance testing of the equipment as it was to be installed at each of the remote sites.

During late 1961, an industrial team headed by the Western Electric Company turned over this $60 million global network to NASA. Other team members were Bell Telephone Laboratories, Inc.; the Bendix Corporation; Burns and Roe, Inc.; and International Business Machines Corporation. At the same time, the Lincoln Laboratory of the Massachusetts Institute of Technology had advised and assisted on special technical problems related to the network. The concluding contract had involved extensive negotiations with federal agencies, private industry, and representatives of several foreign countries in the establishment of tracking and ground instrumentation.

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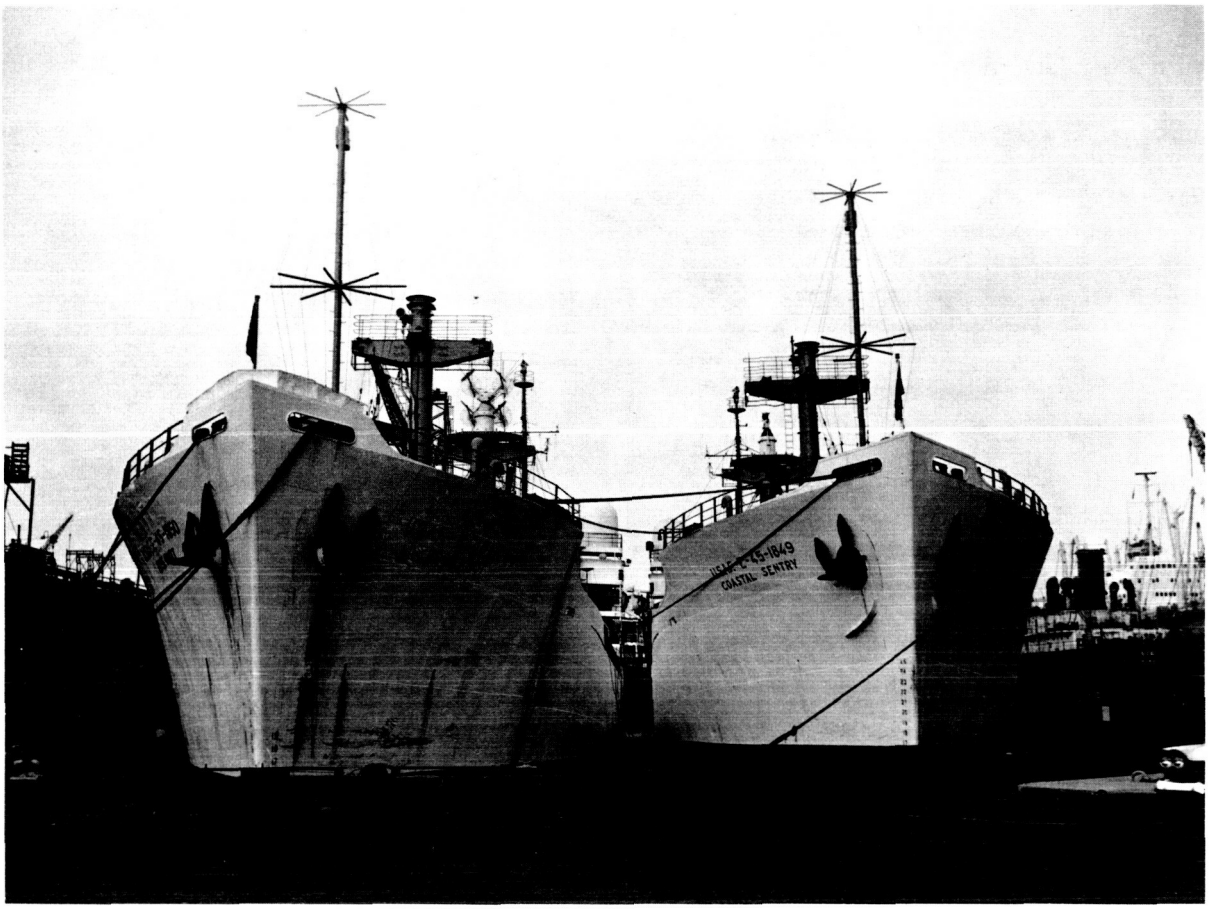


The two tracking ships of the Mercury Network.

This worldwide network consisted of tracking and instrumentation sites (sixteen land-based sites and two ships), a control center, and a computing and communications center and was capable of performing real-time analysis of both the powered phase and orbiting flight. From orbital insertion until landing, the network provided continuous prediction of the capsule location, monitored the status of the capsule and astronaut, and initiated the command functions necessary for the mission.

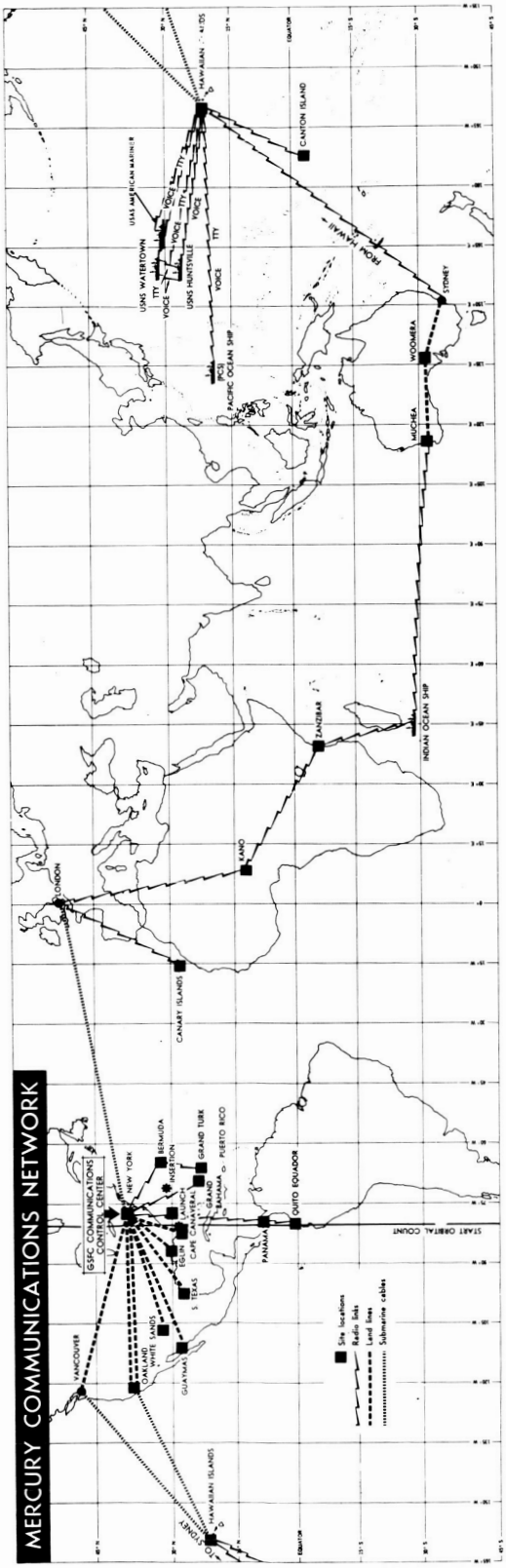
The sites which composed this network are shown in the illustration. The instrumentation which was installed at the sites is discussed below.

Radar Tracking

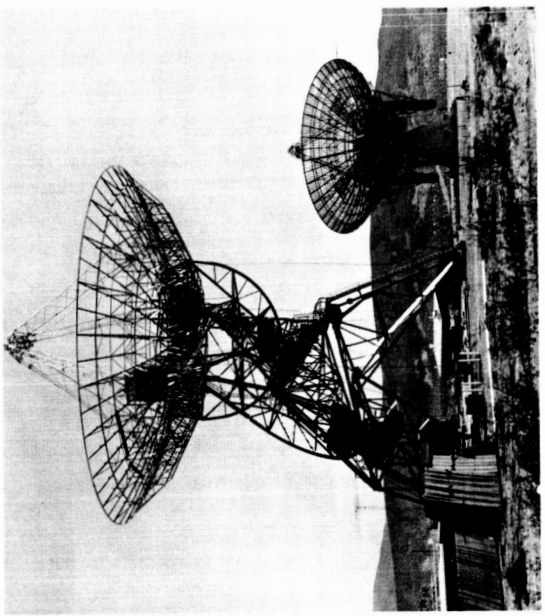
In view of the fact that the computing system, located at GSFC, required a reliable input of tracking data in order to assure accurate presentation of the location of the capsule at all times, it was decided initially that two types of radar would be incorporated. Since the spacecraft was of such a size that skin tracking with conventional radar would not be entirely reliable, it was decided that two radar beacons would be placed on board the spacecraft. The frequencies were selected on the basis of the available existing tracking facilities and resulted in the choice of C-band as well as S-band tracking capability. This provided a degree of redundancy in the event that one of the on-board beacons failed during an orbital flight.

Command

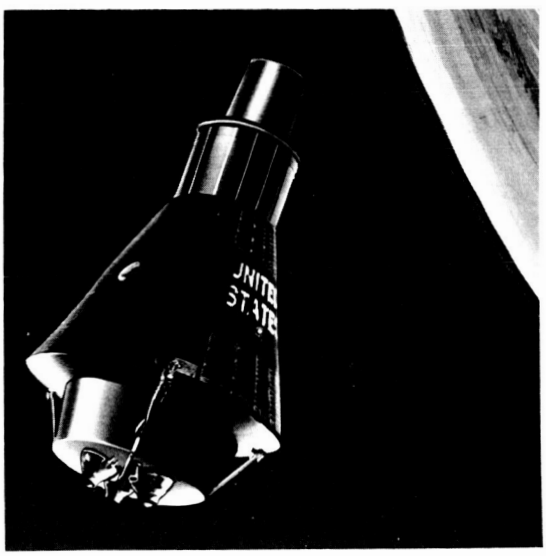
Of almost equal importance in the early consideration of the orbital flight was the capability of backing up the astronaut by ground command. Therefore, at strategic sites throughout



(a) Mercury Network map.



(c) Goldstone antenna.



(b) Mercury capsule.

The Mercury Network.

the network, dual FRW–2 command systems were installed. As it turned out, the use of the command system was required mostly during unmanned ballistic and unmanned orbital flights.

Telemetry

In order that intelligent ground command could be initiated, it was necessary that a high degree of real-time ground monitoring capability be provided for the flight controllers located at the various sites. To implement this, the spacecraft was designed to incorporate a dual telemetry system operating at separate carrier frequencies. Consequently, the ground system had to have the capability of receiving two separate telemetry carriers with the attendant demodulation equipment associated with each.

Spacecraft-to-Ground Communications

To assure a high degree of reliability of spacecraft-to-ground communications under the unknown conditions which might be experienced at approximately a 100-mile altitude, again a dual communications system was incorporated into the spacecraft. This consisted of both ultra high frequency and high frequency communications systems. Consequently, each of the ground tracking sites required the installation of associated receiving and transmitting equipment for these frequencies.

Ground Communications

To interconnect the network tracking sites with a reliable intercommunications system, two means of communications between sites and with the control center were established. The first and basic type consisted of the teletype communications facilities. Not only was it necessary for the teletype communications system to carry the load of communications between the flight controllers located at various sites around the network during the mission, but this system also was designed to deliver the radar tracking data from the radar tracking sites to the central computers. In addition, the ground communications network provided the capability to communicate by voice between the control center and all sites.

Acquisition and Timing

To enhance the reliability of the foregoing tracking systems, such as radar tracking, command, communications, and telemetry, it was recognized that early and reliable acquisition of the spacecraft as it approached each tracking site was of major importance. Therefore, a great deal of emphasis was placed on the system which could reliably provide pointing information to the various tracking antennas as the spacecraft appeared above the horizon. In addition, the provision of accurate radar tracking data, the reliable transmission of commands at a predetermined time, and tagging the received telemetry data with an accurate time reference made it necessary that a universal timing system be installed at all sites. This system utilized the WWV and WWVH radiated time signals for calibration.

Goddard Space Flight Center was the computing and communications center for this network. The two IBM 7090 computers operated in parallel to compute the smoothed present position of the capsule at all times, predict the future position, and shift the coordinates to provide acquisition information for all observation sites.

The Ground Communications Network was an automatic communications system connecting the Mercury sites around the world with GSFC. Any intelligence pertaining to the Mercury capsule—except on life support equipment—passed through GSFC. The system carried telephone, teletypewriter, and high-speed data (1000 bits/second) information to and from the worldwide network on a real-time basis. It accepted a message from a distant site and delivered it to the final destination—regardless of location—in a little over 1 second. The voice communications system was essentially a private-line telephone system which terminates in SCAMA (Switching, Conferencing, and Monitoring Arrangement) at GSFC, where it was capable of being interconnected or switched over various lines.

Altogether, the Mercury system involved approximately 60,000 route miles of communications facilities to assure an integrated network with worldwide capability for handling satel-

James Donegan (seated second from left), Goddard Mercury Operations Director, and staff monitoring the MA-6 Flight.

lite data. It comprised 177,000 actual circuit miles—102,000 miles of teletype; 60,000 miles of telephones; and over 15,000 miles of high-speed data circuits.

THE SPACE OPERATIONS CONTROL CENTER

The various tracking and telemetry stations throughout the world were integrated into a coordinated network through a communications system terminating in the GSFC Space Operations Control Center.

The functions of the Space Operations Control Center were:

1. Control the operation of all tracking, command, data acquisition, and data transmission facilities utilized in support of scientific space vehicles.

2. Coordinate the operation of other ground instrumentation facilities utilized in support of scientific space vehicles, with the exception of certain launch site installations.

3. Insure that operational activities required in support of any spacecraft were properly executed according to the operations plan for the vehicle. In the event of inability to fulfill the operations plan requirements, the control center was responsible for recommending suitable alternative courses of action to the project manager and for making certain that his decision was properly implemented.

4. Provide facilities for monitoring the status of the network and the space vehicle at all times.

5. Insure that the project manager was informed of any departures from nominal in the status of the network or of the satellite which might affect the conduct of the operation.

6. Coordinate data reduction facilities, both for reduction of tracking data for determina-

tion and refinement of the orbit, and also for performance of such computations on the telemetered data as were requested by the project manager. The control center was directly responsible for converting tracking data into formats suitable for data processing.

7. Schedule network activities to insure that the requirements imposed were within the operational capability of the network and to avoid conflicts between individual projects insofar as possible.

8. Provide facilities such that interested officials could follow the critical phases of specific operations and could rapidly obtain information on the status of any satellite during its useful lifetime.

Communications area.

The control center utilized the following facilities in the performance of these functions:

Communications

Ten telephone toll lines, two local voice loop circuits, two special external point-to-point circuits, and ten dial intercom positions provided voice contact between external and internal groups performing functions essential to a given operation. There was also a special voice line to other agencies to pass on satellite orbital data. The center used six walkie-talkie transceivers for voice contact to mobile operators or those operating on a short-term basis.

In addition to the routine in-house routing system for printed messages, the center was tied into the worldwide teletype network via three quasi-realtime data lines and two monitor lines, which provided a minimum of delay on circuits of operational importance.

Display

Three large edge-lit plexiglass boards were available to display manually status, schedules, and graphical data of general interest and importance. An opaque projector was utilized to project teletype messages and information of interest on a screen. Digital clocks displayed time (GMT) : time to liftoff (countdown), and elapsed time of a hold. The clocks could be preset and controlled to indicate the status of the proceedings. A world-map display indicated the nominal orbit on a Mercator projection; and active sites were illuminated to indicate status, acquisition, et cetera. Doppler launch data were superimposed on a nominal curve on a plotting board, indicating launch vehicle performance after liftoff.

Computation

Three small computers were available: the CDC–160, the LPG–30, and an RPC–4000. These machines were utilized to process data of various types and of particular interest into a form for optimum presentation. For example, teletype data were edited and stored on IBM-style magnetic tape for rapid and easy handling. These machines lent themselves to the expeditious solution of last-minute data changes. In addition, they were used to perform various studies to aid in operational planning.

The communications network centering on GSFC included 36 full-period leased teletype lines serving 50 continental and foreign stations in the Minitrack and Deep Space networks, other data acquisition and command stations for scientific satellites, and other agencies in the scientific community engaged in the exploration of space. The 36 circuits (later expanded to 42-line capacity) terminated in a Western Union 111B switching center which combined torn-tape relay, message-switching, and circuit-switching capabilities. Circuit-combining facilities permitted the interconnection of any station in the network in any combination for

Computer operation during the MA–6 mission.

High speed "real-time" computers.

direct conference or real-time data exchange as needed. In addition, six full-period off-net lines were brought into the center. Three TWX, RCA, and Western Union commercial refile services were available. These circuits were used to carry all types of administrative and logistics information, satellite tracking data, satellite prediction and orbital data, and certain types of telemetry data.

All equipment and circuits in the Operations Room were arranged on a patch panel which permitted complete flexibility in interchange or substitution of equipments and links. One of the page printers was equipped with a keyboard for use in keyboard-to-keyboard coordination of data runs with remote stations in the network. Each of the circuits could be directly connected to any station in the network by leg-combining repeaters under switch control. An off-line 19/14 teletype set was provided for special tape preparation.

In the Control Room, two page printers were provided for monitoring purposes. Any lines in the network could be monitored upon request, and outbound traffic from the control room was carried by courier to the communications room. Voice communications in the control room was accomplished with standard telephone equipment. Each of 12 operating positions had the capability of utilizing an outside exchange line, local interposition extensions, or a general conference loop; selected

positions had the capability of point-to-point connection for immediate contact to facilities such as the communications room. The Operations Director, the Project Coordinator, and the Network Controller were able to select any of the lines in the room. Headset transceivers were generally used, leaving the operators' hands free.

THE DATA REDUCTION CENTER

A data processing center was established for determining the orbital parameters of earth satellites and reducing the scientific data obtained by the experiments contained in these satellites.

Computer facilities available at the center included four large-scale general-purpose scientific computers (IBM 7090's) with associated peripheral equipment, as well as a variety of small digital computers, such as the CDC–160 and LPG–30. Scientific data obtained by the satellites were processed by means of special-purpose equipment developed to handle the many different telemetry formats in use. Underlying principles included in the design stressed semiautomatic operation with optimum improvement in the signal-to-noise ratio. Conversion to digital format was a one-step operation allowing rapid entry into a large-scale computer for the complete reduction and analysis phase. Quick-look facilities in the form of tabulation or strip charts gave the experimenters the opportunity to evaluate their data prior to the final reduction and analysis, and hereby determined optimum handling procedures to suit their individual needs.

The objectives of the GSFC orbital calculation programs were to determine and predict the orbits of satellites on the basis of observational data. Initially, the programs were written by the IBM Vanguard group for the Vanguard IGY project. These programs were subsequently replaced by programs written by GSFC personnel incorporating improvements in methods and efficiency. Orbit prediction could be done in four ways: Hansen theory, Keplerian ellipse, Brouwer theory, and numerical integration of equations of motion. The output of these orbit-prediction programs could be supplied in a variety of local frames at arbitrary times and in any form required. The output forms that were used included geodetic latitude, longitude, and height above subsatellite points; azimuth, elevation, and range; local hour angle, declination, right ascension, and direction cosines—all with reference to an arbitrarily selected site on the earth's surface.

Data acquired at the many remote stations had to be processed and reduced. Some of these data were not of uniform quality; therefore, the central data reduction facility had to be extremely flexible and capable of taking into account operational errors. The central facility also had to be able to handle the many varieties of such data as time, etc., which resulted from a lack of standardization of all missile ranges and data acquisition networks. Almost without exception, telemetry data were recorded at the stations on magnetic tape.

The first step in the operation was an inspection and evaluation of the tapes received. Selection for further processing was based on the general requirements that the tapes have signals with adequate signal-to-noise ratio and usable timing, standard frequency, and tape-speed controls. The data were then digitalized and stored on digital magnetic tape. In cases where experimenters demanded analog records such as film or strip-chart recordings, these were supplied. In some instances, this was the only method in which the data could be presented. However, digitalizing did allow rapid entry of the data in a computer and was usually suggested as the preferable method.

The final reduction and analysis of the data in a computer allowed insertion of calibration, linearization, smoothing, selection, correlation with other data and, finally, merging of the data with orbit and aspect data. Mathematical operations on the data, such as insertion into equations relating measured values to other quantities, were easily performed; and the final output to the experimenter could be in the form of tabulation or graphs as desired.

Chapter 6

INTRODUCTION TO THE UNITED STATES SPACE SCIENCES PROGRAM*

The mission and activities of the Goddard Space Flight Center constitute important contributions to the United States space program. To afford the reader an opportunity to review the activities of the Center in a manner which reflects the chronological development of these efforts, excerpts from the report of the National Academy of Sciences dated March 12, 1959, to the Committee on Space Research are reprinted as Chapter 6. *To quote*,

A space sciences program is being developed by the U.S. National Aeronautics and Space Administration on as broad as basis as possible. In the planning and programming, advantage is being taken of the advice of the National Academy of Sciences' Space Science Board and also of specialists and experts in the scientfic community. In the conduct of satellite and space probe experiments broad participation of the scientific community and industry, along with government, is planned, and steps are being taken to secure such participation. The developing program uses and will increase the momentum in space research developed during the International Geophysical Year . . .

Although the program planning is still in its preliminary stages, it is hoped that in each of the next two years between 75 and 100 sounding rockets may be launched and on the order of one or two satellite or space probes every two months.

In the rocket sounding program, emphasis will be placed upon experiments relating to atmospheric structure, electric and magnetic fields, astronomy, energetic particles, and the ionosphere.

The satellite program will emphasize atmospheres, ionospheres, astronomy, energetic particles, electric and magnetic fields, and gravitation.

Space probes will investigate energetic particles, fields, and ionospheres.

Although the approximate magnitude and emphasis of the program has been described, much remains uncertain regarding the special vehicles to be used, their orbits or trajectories, their specific schedules, launching sites, tracking and telemetering support, and special technolgy support.

SPACE SCIENCES PROGRAM

I. Atmospheres

Objectives

To determine and understand the origins, evolutions, natures, spatial distributions, and dynamical behaviors of the atmospheres of the earth, moon, sun, and planets; and their relations to the medium of interplanetary space. To investigate atmospheric phenomena associated with interactions between photons, energetic particles, fields, and matter. To understand the relations between the earth's upper atmosphere and its surface meteorology. To evaluate atmospheric effects on space flight.

Program

(a) *Long Range*

Long-range plans for achieving the above objectives include: (1) instrumented satellite stations around other planets, (2) rocket probes deep into the atmospheres of other planets including soft landings onto the surface with automatic and eventually manned recording

*Report on the second meeting of the Committee on Space Research, held at the Hague, March 12–14, 1959; and letter from U.S. Representative to COSPAR to the President of the Committee on Space Research, dated March 14, 1959.

stations, (3) probes deep into the solar atmosphere, (4) special probes for measuring the density and nature of gas and dust particles in interplanetary space and within comets, and (5) extensive theoretical studies to understand the basic natural phenomena taking place within the atmospheres.

(b) *Immediate*

Short-range plans include extensive and intensive studies of the structure and composition of the earth's atmosphere by direct measurements with sounding rockets and with satellites. Diurnal, latitudinal, and temporal variations in these parameters will be studied and will be correlated with energy and momentum balances in the earth's upper atmosphere. Models of the earth's atmosphere will be formulated for (1) providing basic data needed in understanding ionospheric, auroral, and other phenomena; and (2) providing guidance in the study of the atmospheres of other planets.

Short-range plans for studies up to about 50 miles include scores of synoptic rocket flights and several cloud cover satellites to establish the relationships between surface meteorology and the structure and dynamics of the upper atmosphere.

II. Ionospheres

Objectives

To determine and understand the sources, natures, spatial distributions, and dynamical behaviors of the ionized regions of the solar system, including the ionospheres of the earth, moon, and planets. To investigate ionospheric phenomena resulting from interactions between photons, particles, ions, and magnetic, electrostatic, and electromagnetic fields. To understand relations between solar activity and the terrestrial and other planetary ionospheres, magnetic fields, and upper atmospheric current systems. To evaluate ionospheric effects on space flight, including communications.

Program

(a) *Long Range*

The long-range program will exploit present techniques for determining the terrestrial ionospheric structure, its propagation characteristics, and its influence on space flight by observation from below, within, and above. New techniques for evaluating the least known parameters will be developed. All of the applicable methods will then be used for the study of other planetary ionospheres. Eventually, propagation sounding stations may be established on the surface of the moon. All the data will then be applied to understand the interrelations between solar activity, magnetic fields, the aurora, the Great Radiation Belt, and other phenomena.

(b) *Immediate*

The immediate program is concerned with obtaining electron density profiles at altitudes above the F_2 layer by inclusion of proven propagation experiments in space probes. Concurrently latitude and temporal variations of this parameter will be obtained by use of a polar orbiting satellite beacon. Topside sounders in satellites will be used for synoptic studies of electron density in the outer ionosphere. This technique promises lesser ambiguity than that obtainable from satellite beacons. Present knowledge of electromagnetic propagation will be extended by inclusion of very low frequency receivers in polar-orbiting satellites. Ion spectrum studies will be extended to lower mass numbers and higher altitudes by inclusion of rf mass spectrometers in space probes and satellites. Direct measurements using devices such as antenna probes, ion probes, and electric field meters will be made in rockets and satellites, to better define ionospheric structure and to study the interaction between the ionosphere and space vehicles.

III. Energetic Particles

Objectives

To determine and understand the origins, natures, motions, spatial distributions, and temporal variations of particles having energies appreciably greater than thermal. To understand their relation to the origin of the universe. To understand interactions between such particles, fields, photons, and matter. To evaluate possible hazards to life and other effects of energetic particles and photons in space.

Program

(a) *Long Range*

In situ measurements using deep space probes will be made from the close proximity of the

Visitors from abroad tour Goddard Space Flight Center.

sun to the limits of the solar system. Extensive measurements in the vicinity of the planets, especially the earth, will be made to determine the interactions of the energetic particles with the atmospheres and fields of these bodies. These measurements will require satellite orbits around the earth, the moon, and other planets. The establishment of an observatory on the surface of the moon or on some other planet might be desirable, depending on the data previously acquired by artificial satellites.

(b) *Immediate*

In the near future the measurement of energetic particles will be pursued with satellites and rockets in the vicinity of the earth and with interplanetary probes. These measurements will be aimed at determining the interactions of these particles with the earth's atmosphere and field, their interactions with interplanetary fields, the types and energies of these particles, their spatial distribution, and the origin of the energetic particles.

The immediate program includes specifically measurements of the cosmic ray intensity in interplanetary space; of time and latitude cosmic ray intensity variations; of the composition and spatial extent of the Great Radiation Belt; of the cosmic ray energy and charge spectrum; and of the nature of the particles producing auroras.

IV. Electric and Magnetic Fields

Objectives

To determine and understand the origins, natures, methods of propagation, spatial distributions, and temporal variations of magnetic and electric fields throughout the universe. To understand interactions between these fields and matter in space, and the influence of existing fields on solar and planetary atmospheres. To use these fields in the investigation of the internal constitution of astronomical bodies. To evaluate their effects and interactions on space flights.

Program

(a) *Long Range*

Results from satellites, probes, and rockets to be flown in 1959 will be an important factor in determining the long-range program for studying the earth's fields. One can, however, anticipate that an important item will be establishing an earth satellite observatory which will include instruments for measuring particle flux and solar radiations as well as magnetic and electric field instruments such that direct correlations can be made between the various phenomena. Also rocket soundings into the ionosphere will continue to study details of ionospheric currents more thoroughly.

Attempts will be made to measure the fields of the Moon, Mars, and Venus from probes making close approaches and eventually from packages landing and serving as observatories.

Probes will be launched toward the sun to obtain solar field measurements as close to the sun as feasible.

Theoretical analyses and correlations between electric and magnetic field phenomena and other phenomena will be an integral part of the program.

(b) *Immediate*

The short-range magnetic field program includes the use of sounding rockets, satellites, and space probes to carry magnetometers for investigation of the existence of ring currents above the ionosphere during magnetic storms, ionospheric currents, information on radiation belt currents, for measuring electric currents and the form of the earth's field at great distances, interplanetary fields, and the moon's magnetic field, and to study the complete spectra of field variations and for comprehensive field mapping.

It is also anticipated that simple magnetometers which can detect only the existence of a perceptible field will be placed in several rockets and space vehicles as secondary experiments.

The short-range electric field program includes the use of electric field meters and Langmuir probes to explore satellite charging and ion sheath characteristics.

V. Gravitational Fields

Objectives

To determine and understand the origins, natures, methods of propagation, spatial distributions, temporal variations, and effects of gravitational fields throughout the universe. To determine and understand the external form and internal constitution of the earth, planets, and stars. To determine and understand the relations between gravitational and electromagnetic fields. To evaluate effects of gravitational fields of different magnitudes, including weightlessness, on space flights.

Program

(a) *Long Range*

For the study of the fundamental nature of the gravitational fields, two avenues are opened by the ability to launch satellites and space probes. The first of these is the ability to try experiments on a scale of hundreds and thousands of kilometers by probing the fields of planetary masses with bodies capable of being accurately observed. This is significant because gravitational fields, except that of the earth, are almost unmeasurable in laboratory-scale experiments. In the second place, the periods of artificial satellites are so much shorter than those of the moon and other natural satellites that in a few years a number of revolutions corresponding to thousands of years for natural satellites may be observed.

By the first avenue, it is possible to seek the links which must exist between the theory of the electromagnetic field and gravitational field. It is planned in particular to test the equality of gravitational and inertial masses by experiments in space which are a repetition of the experiment of Galileo in the Leaning Tower of Pisa. An attempt will be made to devise experiments which will reveal the velocity of propagation of gravitation, if any.

It is planned to determine the masses of the inner planets by direct observation of probes passing near them or possibly around them. These probes will at the same time help to determine the value of the astronomical unit.

It is planned to test the hypothesis that gravitational attraction depends on the average density of matter in the universe and that it therefore is slowly weakening as the universe expands. For this purpose, it is planned to compare an atomic clock on the ground with a gravitational clock of some kind. A proposal for a gravitational clock consisting, in effect, of a high satellite with a very well measured orbit is being studied.

It is planned to employ moon probes to obtain improved values for the overall mass of the moon and for the moments of inertia about its three principal axes. It is planned to attempt to determine the strength of the materials in the moon's interior from this information.

It is planned to measure the mass of Venus and of Mercury in order to test Bullen's ideas about the nature of the cores of the planets.

Using the second avenue, it is planned to observe the motions of close satellites of the earth over a long period and to make precise comparison with theory, searching for systematic trends in the inclination and the eccentricity, which might shed light on the history of the solar system.

(b) *Immediate*

(1) Studies are now being made on existing satellites with the object of determining the low harmonics of the earth's field from tracking data.

(2) It is also planned to put into orbit a special geodetic satellite which will be capable of refining the observations on the harmonics, and of determining intercontinental distances with high precision. It should be possible to carry the study of the form of the geoid much further than has been possible to date.

The information developed in (1) and (2) above will be applied to the question of the basic hypothesis of geodesy. This hypothesis, as formulated by some theorists, is in essence that the low harmonics of the earth's gravitational field have amplitudes of a meter or so. The hypothesis is not universally accepted; other theorists consider that the amplitudes are on the order of scores of meters. A decision between these two hypotheses is important because Heiskanen, in particular, proposes extensive work revolving around the Stoke's Theorem—work which is only warranted if the basic hypothesis is satisfied. This information will also be used in an attempt to evaluate hypotheses of convection in the mantle. These hypotheses seem to go with the ideas of the first-mentioned school of theorists, and it may be possible to decide between these hypotheses and the alternative contraction hypothesis on the basis of our information.

(3) It is planned to put in orbit a satellite carrying a very precise clock in order to test a theory of Einstein which predicts a change in the clock's speed depending upon the strength of the earth's gravitational field.

VI. Astronomy

Objectives

To determine the spatial distributions of matter and energy over the entire universe, and to understand their cosmological origins, evolutions, and destinies. To observe from above the earth's atmosphere the spectral distributions of energy radiated from objects in the solar system, in this and other galaxies, and in the intervening space, with emphasis on observations that are prevented or comprised by the absorption, background emission, and differential refraction of the earth's atmosphere. To determine and understand the geology of the planets. To determine the effects of meteors, radiations, and other astronomical influences on space flights.

Program

(a) *Long Range*

The first phase of the long-range program will be the development of an orbiting and stabilized platform. With such a platform, it will be possible to orient a wide range of telescopic instruments so as to make detailed observations of specific quantities of interest at selected locations on the celestial sphere. Command control for the platform will be incorporated so that redirection of the instrumentation will be possible. The obvious advantages of observations made beyond the earth's atmosphere will be available to us with such an orbiting observatory. There will still remain some observational difficulties because of the back scattered light of the sun and the Doppler shifts resulting from the high velocity of the satellite.

(b) *Immediate*

The immediate program will continue and extend to the Southern sky the survey of the newly discovered nebulosities in the far ultraviolet by means of rockets. These measurements are being undertaken to determine the nature and sources of these emissions. Concurrently stellar photometry measurements will be made in the near and far ultraviolet spectrum region to extend magnitude systems to ultraviolet. Emphasis is being given to extending observations into the previously unexplored far infrared and high energy gamma-ray spectral regions by means of scanning satellites and rockets. Apart from their intrinsic value, these surveys are essential as ground work for the satellite observatory program.

Studies of the solar ultraviolet and X-ray spectra will be extended to include long term variations, line profiles, distribution across the disk, and the spectra of the coronal X-ray flux. These studies will be carried out in a series of rocket firings and with satellite-borne pointing devices.

Deep space probes will be used to determine the nature of the interplanetary medium.

Satellites will be used to map the emissions of the high atmosphere which arise from charged particle interactions and photochemical reactions.

VII. Biosciences

Objectives

To determine the effects on living terrestrial organisms of conditions in the earth's atmosphere, in space and in other planetary atmospheres; and of flight through these regions. To investigate the existence of life throughout the solar system, and to study such life forms in detail. To develop information necessary to achieve and maintain healthful artificial environments for terrestrial organisms, including man, throughout the solar system.

Chapter 7

GODDARD SATELLITES, SPACE PROBES, AND SOUNDING ROCKETS

The following pages constitute a summarized report of Goddard Space Flight Center satellites, space probes, and sounding rockets launched up to December 31, 1962.

Several U.S. scientific satellites were launched under the aegis of other governmental agencies before GSFC successfully orbited Explorer VI on August 7, 1959.

Although the full analysis of the scientific results of these earlier launches had not been published in final form at the time of the first Goddard launch, some of the preliminary reports provided knowledge which was helpful to the Goddard projects in process. Because of the implications and impact of the experience gained from these earlier launches on later Goddard experiments, they are included in this report.

U.S. SATELLITES LAUNCHED PRIOR TO GSFC LAUNCHINGS

1958

In 1958, five successful launches were made.

Explorer I (1958α1)

Launched February 1, 1958, under the project direction of the Army, Explorer I was the first U.S. satellite placed in an earth orbit. It was responsible for the discovery of the Van Allen radiation belts—believed to be the most significant finding of the International Geophysical Year. It demonstrated the feasibility of temperature control by satellite surface treatment and showed that micrometeorites are not necessarily a major consideration in space travel near the earth.

Vanguard I (1958β2)

Launched March 17, 1958, Vanguard I was a Navy test of the Vanguard launch vehicle and satellite ejection mechanism. By being placed in an earth orbit, it determined atmospheric density at great altitudes and conducted geodetic measurements. It revealed that the earth is slightly pear-shaped, and the extensive information gained from it will be useful in correcting geophysical map errors. It revealed much about the pressure of solar radiation, and pioneered the use of photocells as a solar power source. It is the oldest man-made object in space and is still transmitting. Its lifetime, originally estimated at 200 years, is now believed to be about 2000 years.

Explorer III (1958γ1)

Explorer III, launched by the Army on March 26, 1958, went into an orbit slightly more elliptical than that planned. However, it yielded valuable data on radiation belts and micrometeor impacts as well as external and internal temperatures. It came down on June 27, 1958.

Explorer IV (1958ε1)

Launched July 26, 1958, under the project direction of the Advanced Research Projects Agency of the Department of Defense, Explorer IV was for the purpose of studying radiation belts detected by Explorers I and III and for measurement of artificial radiation created by previous experiments by DOD. It successfully provided information on radiation belts and collected data to establish detailed spatial relations and many of the properties of the artificial radiation, and aided in analysis of the earth's magnetic field.

Project Score (1958ζ1)

Launched December 18, 1958, also under the project direction of the Advanced Research Projects Agency, Project Score tested the feasi-

bility of the Atlas ICBM as a space vehicle. It also tested the feasibility of voice and teletype relay via satellite. By its use, for the first time a human voice (President Eisenhower's) was beamed from outer space. It was the first known satellite to be guided into orbit by a radio-inertial system. Its beacon signal terminated December 19, 1958; and the voice signal stopped on December 31, 1958. It was down on January 21, 1959.

1959

In 1959, prior to Goddard's successful launch of Explorer VI, three satellites and one space probe were launched by the United States.

Vanguard II (1959α1)

This satellite, launched under NASA project direction on February 17, 1959, was placed in orbit for the purpose of studying the earth's cloud cover. While the satellite was successfully placed in orbit, a wobble which developed prevented interpretation of the cloud-cover data. The payload configuration was that of a sphere with a shell of highly polished silicon-monoxide-coated magnesium. The tracking transmitters' batteries lasted for 27 days.

Discoverer I

Discover I was launched under the project direction of the Advanced Research Projects Agency on February 28, 1959. Its objective was to demonstrate the orbital capability of the Discoverer-Thor combination and the capability of its ground support equipment.

The satellite was placed in near-polar orbit. Difficulty in stabilization caused tumbling, which hampered continuous tracking. Transmitters included telemetry and a tracking beacon. The satellite reentered the atmosphere and decayed within a short time.

Pioneer IV (1959ν)

Launched by NASA on March 3, 1959, this instrumented probe was placed in an Earth-Moon trajectory to measure radiation in space, to test the photoelectric sensor in the vicinity of the moon, to sample the moon's radiation, and to test long-range tracking.

Pioneer achieved an Earth-Moon trajectory and yielded important radiation data in space. An injection below the planned velocity prevented near-lunar experiments. The configuration of this probe was conical with a shell of gold-washed fiber glass, which would serve as a conductor and antenna. It was tracked for 82 hours and to a distance of about 407,000 miles. It is in orbit around the sun.

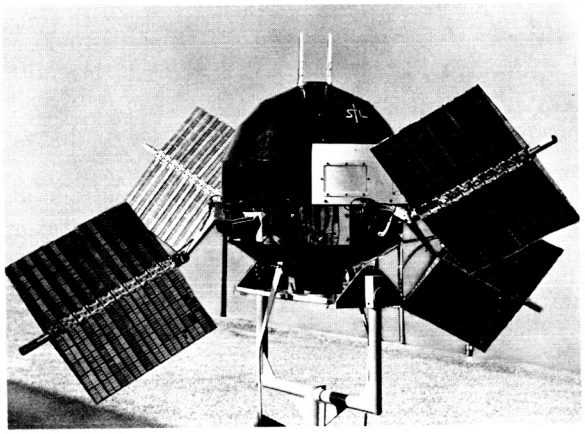
Discoverer II

Launched on April 13, 1959, by the Advanced Research Projects Agency of the Department of Defense, its objective was to provide data on propulsion, communications, recovery techniques, and the measurement of cosmic radiation.

It achieved a near-circular orbit, and stabilization was controlled. The timer malfunctioned and caused a premature capsule ejection, and a recovery attempt was prevented.

Discoverer II was the first satellite to carry a recoverable instrument package. The telemetry ran to April 14, 1959, and the tracking beacon to April 21, 1959. The capsule made impact in the vicinity of the Spitsbergen Islands (Arctic Ocean) and was lost.

The following sections provide basic information, by years, on successful launchings by Goddard Space Flight Center of scientific satellites, space probes, and sounding rockets. These data cover the period from the date of Goddard's activation until Dec. 31, 1962.



Explorer VI, launched August 7, 1959.

SATELLITES AND SOUNDING ROCKETS LAUNCHED BY GSFC IN 1959

Satellites

Explorer VI (1959δ1)

Launched on August 7, 1959, Explorer VI was the first scientific satellite under the project direction of Goddard Space Flight Center.

This satellite contained instruments for measurements in the Van Allen radiation belt region, provided by the Universities of Chicago and Minnesota and by the Space Technology Laboratories. It also contained instrumentation for the measurement of the earth's magnetic field and for a type of one-line television scanning of the earth's cloud cover, provided by the Space Technology Laboratories. NASA and the Air Force Cambridge Research Center provided equipment for the measurement of micrometeorites. Stanford University provided equipment for the observation of very low frequency radio signals.

The results of this experiment are the following:

University of Chicago

1. High-energy (10–20 Mev) radiation on the inner side of the radiation belt region. This appears to be a narrow proton band, 330 miles (500 km) thick, at about 1240 miles (2000 km) out from the earth. The total counting rate at maximum is about 1400 counts/cm²-sec.

2. In the vast outer low-energy radiation region, no protons are observed with energies greater than 75 Mev, or electrons with energies greater than 13 Mev.

3. There are indications of variation with time.

University of Minnesota

1. The intensity of the radiation region at great distances dropped to a much lower level than was noticed by Van Allen in the Pioneer probes—5000 times less than Pioneer IV and 10 times less than Pioneer III (1958θ1).

2. Maximum intensity was at 13,640 miles (22,000 km) from the earth's center.

3. The radiation regions show a pronounced and complicated structure.

4. An attempt is being made to map the radiation levels and to study the character of the radiation by the relative responses of the different instruments.

5. This instrumentation shows the same region of hard radiation as that found by the University of Chicago.

6. Toward the end of August, the radiation layers were filling up at large distances and had reached an intensity comparable with that of Pioneer III.

7. There are some pockets of radiation at large distances which appear and disappear with time. The increase appears to be correlated with solar outbursts.

Space Technology Laboratories

1. On August 20, during a solar eruption, the maximum intensity was observed to increase by a factor of 10 to 100 from the maximum on quiet days.

2. However, on August 16, when there also was high solar activity and an intense magnetic storm, there was no increase recorded.

3. Fluctuations of intensity indicate that both the inner and outer zones are much more complicated than has been previously indicated.

4. One hundred forty traversals of the radiation belt region indicate that the low energy radiation zone has a gross structure similar to the radiation belts reported by Van Allen.

5. The television scanner data give a very crude image which correlates roughly with data from meteorological maps.

6. The reduction of data from the magnetic field experiment is quite involved. No unexpected findings have yet been produced.

NASA and the Air Force Cambridge Research Center

1. Preliminary data analysis indicates a relatively low micrometeor counting rate, compared with data obtained from earlier experiments.

Stanford University

1. The signal from the Navy's very low frequency 15.5 kc/sec transmitting station NSS was received clearly below the D-region of the ionosphere, but dropped out after passage through the D-region at 43.4 miles (70 km) altitude.

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Vanguard III (1959η1)

Vanguard III was launched on September 18, 1959. Weighing 50 pounds, the satellite achieved an apogee of 2329 miles and a perigee of 319 miles.

Experiments—Solar x-radiation, by the Naval Research Laboratory; micrometeorite and satellite temperatures, by the Goddard Space Flight Center.

Results—

Naval Research Laboratory: Because of the high apogee, the solar radiation ionization chamber saturated most of the time, making it impossible to pick up the solar x-radiation; however, good information is being obtained on the structure of the lower edge of the Van Allen radiation belts.

Goddard Space Flight Center: The magnetometer worked well, and preliminary analyses of selected portions of the data indicated that in some locations systematic deviations occur from the predicted fields. The erosion experiments have not indicated that any appreciable erosion has taken place. The micrometeorite experiment has reported from 4 to 15 impacts of particles 10^{-9} gm or larger/m^2/hr. Payload temperature varied between 6° and 27° C.

Explorer VII (1959ι1)

Explorer VII was launched on October 13, 1959; it weighed 91.5 pounds. It has an apogee of 680 miles and a perigee of 342 miles.

Experiments—Solar Lyman-alpha and x rays, by the Naval Research Laboratory; heavy primary cosmic rays, by the Research Institute for Advanced Study of the Glenn L. Martin Company; total cosmic ray counting rate, by the State University of Iowa; the radiation balance in the earth's atmosphere, by the University of Wisconsin; micrometeorites and satellite erosion, by Goddard Space Flight Center; and satellite temperatures.

Results—

1. The 20 Mc transmitter is functioning properly on solar power supply and will probably continue for many months. The 108 Mc transmitter exhausted its chemical batteries and stopped transmitting in December 1959. All data are in early stages of analysis, and results are very tentative.

2. The meteorological radiation balance experiment is yielding approximately 1000 measurements per day. The sensitivity is sufficient to distinguish hot and cold air masses at night and cloud cover in daylight; comparison with balloon-borne radiometers indicates reasonable accuracy with respect to the measurement of net outward energy flux.

3. Further mapping of variations in the trapped radiation seems to be giving additional evidence of correlation with magnetic storms.

4. The "heavy" cosmic ray experiment seems to be functioning properly; data are still being processed.

5. As expected, the solar x-ray and ultraviolet experiments are adversely affected part of the time by trapped radiation. No solar data have yet been obtained, but it still hoped that a sizable solar disturbance may occur at a time when these instruments will be able to record the accompanying radiation.

6. No significant micrometeorite penetrations or erosion have yet been observed, nor have the solar cells indicated any change in operation during the first 80 days.

7. Internal temperature has varied from 19° to 42° C as the orbit changed from minimum to maximum time in sunlight.

GSFC-LAUNCHED SATELLITES, SPACE PROBES, AND SOUNDING ROCKETS IN 1960

This section summarizes activities and results during the period from about January 1960 to December 1960.

New Results From Previously Launched Satellites*

During the period since January 1960, satellites launched before that date have continued to yield large quantities of data of scientific value. The new data and the results derived from them have been chiefly in the following fields: the fine structure of the earth's gravitational field, relation of air density to solar radiation and activity, the structure of the Van Allen belts and their interconnection with solar

* Including a number of projects undertaken prior to establishment of Goddard Space Flight Center. Experiments concluded under these projects have been incorporated into the GSFC mission.

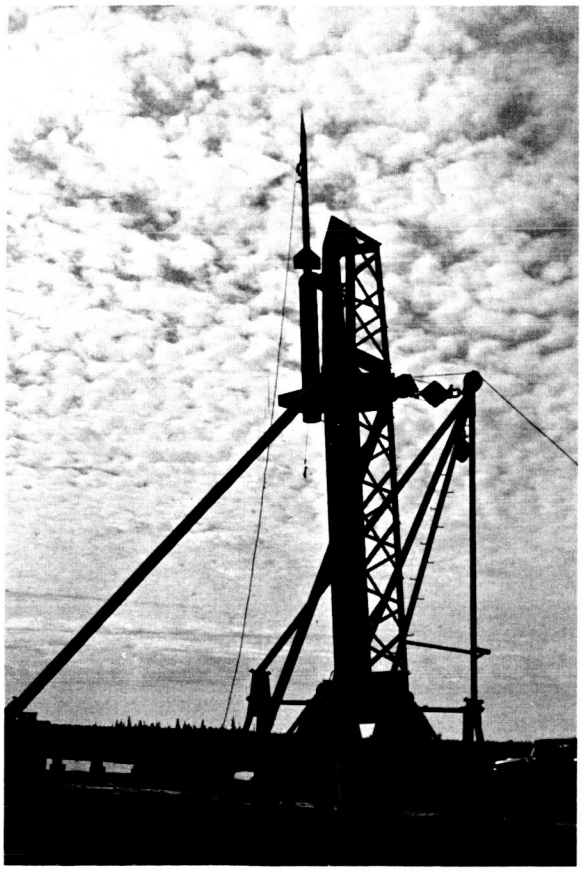
Sounding Rockets

GSFC Sounding Rocket Flights, 1959

Vehicle*	Firing			Project Scientist*	Experiment	Result†
	Date	Site†	Performance*			
Arcon 1 T	May 14	WI	X	Medrow	Rocket test	S
Arcon 2 T	15	WI	X	Medrow	Rocket test	S
Arcon 3 T	15	WI	X	Medrow	Rocket test	X
Arcon 4 T	Aug. 7	WI	X	Medrow	Rocket test	X
Arcon 5 T	7	WI	X	Medrow	Rocket test	X
Arcon 6 T	7	WI	X	Medrow	Rocket test	S
Aerobee 150						
8 I	Sept. 11	FC	S	Jackson	Ionosphere	S
7 I	14	FC	S	Jackson	Ionosphere	S
Arco D-4						
1 T	Dec. 22	WI	S	GSFC/NRL/DRTE	X248 Vibration test	S

*T—Test & support
I—Ionospheric physics
S—Successful
X—Unsuccessful

†WI—Wallops Island, Va.
FC—Fort Churchill, Canada
DRTE—Defence Research and Telecommunications Establishment



Sounding rocket readied for launch at Fort Churchill.

activity and auroras, and ionospheric structure deduced chiefly from propagation phenomena.

The refined optical tracking made possible by the Smithsonian Astrophysical Observatory's network of Baker-Nunn cameras has provided data for increasingly precise orbital analyses for a number of satellites, including Vanguard I. From these data the zonal harmonic coefficients J_3 through J_5 have been determined or further improved, although disputes about the reality of such coefficients possibly will not be completely allayed until more even geographic tracking coverage is provided. More recently, the previously suspected existence of the sectorial harmonic A_{22}, corresponding to an elliptical equator with the major axis 400 meters longer than the minor axis pointing toward longitudes 33° W and 147° E, has been supported by analysis of the motions of Vanguard II and Vanguard III.

This same mass of accurate tracking data has made possible improved and more detailed analyses of the rate of shortening of satellite periods produced by air drag. In particular, the simultaneous effect of the solar event of November 13, 1960, on seven different satellites, including some launched before 1960, has provided dramatic confirmation of the interaction

between the solar activity and the upper atmosphere. In addition, the diurnal effect (with the maximum drag in a region somewhat east of the subsolar point) has been refined to the point where it now can be included in the mathematical representation of the orbital elements.

As data on energetic particles and fields have continued to accumulate or previously acquired data have been reduced from such satellites as Explorer IV, Explorer VI (which is still transmitting), Vanguard III, and Explorer VII, and as these data have been intercompared with each other and with those from other satellites and space probes, knowledge of the extent and constitution of the Van Allen belts has been increased and refined. The effect of solar activity on these factors has been revealed. The very profound effects of solar storms on the outer belt have been discovered; for example, great changes in intensity and extent were detected during the disturbance of March 31, 1960, during which the outer belt first nearly disappeared, then returned to greater-than-normal intensity, and finally fell back to normal levels. The fine structure of the outer belt has been discovered and mapped. Magnetometers of Explorer VI confirmed the existence of a ring current circling the earth about 6 radii out. Magnetometers on Vanguard III and correlated data from ground magnetic observations have mapped the geomagnetic field (including details like the Capetown anomaly) and provided information about its stability and the effect of magnetic storms. The foregoing have been correlated also with auroral activity.

Many large and small time variations in the intensity of the radiation in the radiation belts and in the magnetic field have received only cursory attention and contain a wealth of interesting phenomena which still require interpretation. All the foregoing new facts have led to fresh attempts to construct physical models of the interaction between radiation of solar origin, cosmic rays, the interplanetary medium, the geomagnetic field, and the upper atmosphere.

Finally, satellites still transmitting radio signals, or those previously transmitting signals but for which the data had not been completely reduced, afforded many opportunities for studying ionospheric propagation effects (reflection, refraction, fading of various peculiar types, rotation of the plane of polarization, etc.). From these, additional information on the concentration and distribution of electrons in the ionosphere have been deduced.

1960 Satellites and Probes

Several Goddard-managed satellites and probes were launched during the period January 1 to December 31, 1960. Brief descriptions of these projects and some of the highlights of the scientific results obtained are given below.

Pioneer V (1960α)

The interplanetary spacecraft, Pioneer V, was launched on March 11, 1960, at which time it was over 20,460,000 miles (33 million km) from the earth and 7,440,000 miles (12 million km) inside the earth's orbit. Communications were lost prematurely at that time, probably because of a battery failure.

Some of the technological advances resulting from this project were: (1) an integrated system of tracking, telemetry, and command which required only one communication link; (2) a system of varying the range for useful telemetry transmission by adjusting, from the earth, the transmitter power and information rate used by the spacecraft; (3) an accurate radio system for spacecraft guidance; and (4) telemetered data on the spacecraft performance.

Pioneer V was spin-stabilized and carried two sets of radiation detectors: an integrating ionization chamber and a Geiger-Mueller tube combined in a single package, and a proportional counter telescope. The vehicle also carried a magnetometer to measure the component of the ambient magnetic field perpendicular to the spin axis of the vehicle. A micrometeorite detector and a device for determining the attitude of the vehicle relative to the sun were also included, but failed to function properly.*

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* Arnoldy, R. L., Hoffman, R. A., and Winckler, J. R., *Journal of Geophysical Research*, Vol. 65, No. 5, pp. 1361–1376, May 1960.

Fan, C. Y., Meyer, P., and Simpson, J. A., *Proceedings of the First International Conference on Space Research*, North-Holland Publishing Co., Amsterdam, 1960.

Judge, D. L., McLeod, M. G., and Sims, A. R., *Trans. IRE Space Electronics and Telemetry*, SET-6, No. 3–4, pp. 114–121, September–December 1960.

The scientific results obtained from the instruments aboard Pioneer V provide an example of the knowledge which the program of space exploration has contributed to mankind. The data have not been analyzed completely. However, the experimenters have already reported significant findings, described below under appropriate headings.

Galactic Cosmic Rays—The frequently observed sharp decreases in the intensity of galactic cosmic rays, called Forbush decreases, are phenomena of solar origin and are not caused by the earth or its magnetic field.* This fact was determined by a comparison of data from Pioneer V with simultaneous observations obtained from ground-based neutron monitors. The comparison showed that the magnitude of the large Forbush decreases of April 1, 1960, in the vicinity of the earth was almost identical with that observed at the position of Pioneer V 3,100,000 miles (5 million km) closer to the sun.

The mechanism which produces the 11-year variation in cosmic-ray intensity is centered in the sun, and the size of the volume of space in which the intensity is reduced is greater in radius than 1 astronomical unit during that part of the solar cycle which was covered by the Pioneer V measurements.† This result is inferred from the fact that the reduction in intensity produced by this mechanism was nearly the same at the earth and at Pioneer V.

The radial gradient of the omnidirectional galactic cosmic-ray intensity is -15 ± 20 percent per astronomical unit measured near the orbit of the earth, and in the direction of the sun. This result suggests that any electromagnetic mechanism which accounts for the 11-year variations of the galactic cosmic-ray intensity is located principally outside the orbit of the earth.†

Solar Cosmic Rays—Cosmic rays were observed in space, completely free of any effects due to the earth. Instruments aboard Pioneer V directly detected particles accelerated by solar flares, which constitute a potential hazard to man in space. Numerous bursts of such particles were observed with the ionization chamber–Geiger tube package. The correlation between these observations and data, from ionosondes at Thule and Resolute Bay, on the minimum ionospheric reflection frquency F_{min} indicates that the particles detected in the bursts detected were solar protons, with energies probably between 10 and 50 Mev, and that very few, if any, solar electrons above 50 Mev result from flares.‡ Many of these proton events were detected by the counter telescope also.§ However, the threshold of this instrument for proton detection was about 75 Mev, whereas that for the ionization chamber–Geiger tube package was about 20 Mev.

Those solar flare particles, which produce ionization in the polar atmosphere for many successive hours, are not stored in the geomagnetic field. This fact was established by a comparison of data received from Pioneer V with polar cap absorption data acquired simultaneously.§

The energetic electrons in the earth's outer radiation zone arise from an acceleration mechanism within the geomagnetic field rather than from direct injection of energetic electrons into the field. This conclusion was based on the fact that the flux of electrons of energies in the 50-Bev range reached very high levels in the outer radiation zone, according to Explorer VII data, while few, if any, electrons of these energies were detected at Pioneer V.‖

Bremsstrahlung-producing radiation, evidently accelerated by solar activity, is present in interplanetary space during the periods of such activity.** This type of radiation was detected by the proportional counter telescope on numerous occasions.

* Fan, C. Y., Meyer, P., and Simpson, J. A., *Physical Review Letters*, Vol. 5, No. 6, p. 269, September 1960.

† Fan, C. Y., Meyer, P., and Simpson, J. A., *Physical Review Letters*, Vol. 5, No. 6, p. 272, September 1960.

‡ Arnoldy, R. L., Hoffman, R. A., and Winckler, J. R., unpublished communication.

§ Fan, C. Y., Meyer, P., and Simpson, J. A., *Journal of Geophysical Research*, Vol. 65, No. 6, p. 1862, June 1960.

‖ Arnoldy, R. L., Hoffman, R. A., and Winckler, J. R., *Journal of Geophysical Research*, Vol. 65, No. 9, p. 3004, September 1960.

** Fan, C. Y., Meyer, P., and Simpson, J. A., *Physical Review Letters*, Vol. 5, p. 269, 1960.

The Geomagnetic Field—The termination of the geomagnetic field was observed at about 14 earth radii on the daylight side of the earth, at least during periods of little geomagnetic activity.* The distance from the earth of this termination is considerably greater than that predicted by most theories.

An anomaly in the geomagnetic field was observed at about 6 earth radii on the daylight side of the earth.* This deviation from the assumed dipolar character of the field was similar to that observed with the earth satellite, Explorer VI, on the night side of the earth.† The anomalous component of the field is believed to be produced by a ring current circling the earth with its axis parallel to the geomagnetic axis.‡

The existence of rapid fluctuations in the geomagnetic field between 10 and 14 earth radii was confirmed.§ This phenomenon was first observed with instruments aboard the space probe Pioneer I in October 1958.‖ These fluctuations may be produced by the interaction of the geomagnetic field and the ionized particles therein with the interplanetary medium.**

Magnetic Fields in Interplanetary Space—During periods of low solar activity, the interplanetary magnetic field was found to be about 2.7×10^{-5} gauss and nearly perpendicular to the plane of the ecliptic.††

During periods of solar activity, fields greater than 50×10^{-5} gauss were observed. The direction of the fields at such times could not be determined. The correlation of these increases in the interplanetary field with solar and terrestrial effects leads the experimenters to conclude that these high fields accompany the plasma ejected from the sun during active periods. Further, these comparatively intense fields are believed to be responsible for the exclusion of galactic cosmic rays from regions of the solar system during Forbush decreases.‡‡

Measurement of the Astronomical Unit—The astronomical unit, expressed in the terms of solar parallax, was found to be 8.79738 $\pm$0.00082 seconds of arc.§§ This result, determined from the long-range tracking of Pioneer V, is in good agreement with the value of 8.79835 seconds of arc obtained by Rabe from optical observations of the asteroid Eros.

Tiros I (1960β2)

Tiros I was launched into a near-circular orbit of 428.7 miles (690 km) perigee and 465.9 miles (750 km) apogee on April 1, 1960. Shaped like a hat box, it was about 21 inches (48 cm) high and 42 inches (107 cm) in diameter and weighed about 270 pounds (123 kg). The top and sides were covered with solar cells, the primary source of power. Its main sensors were two TV camera systems. When viewing the earth vertically, one camera took pictures about 700 to 800 miles on the side, while the other took more detailed pictures about 80 miles on the side. Since it was spin-stabilized, the cameras could view the earth during only part of each orbit. Tape recorders made it possible to store pictures taken over areas distant from the United States and to read them out as the satellite passed over the command and data acquisition stations at Fort Monmouth, N.J., and Kaena Point, Hawaii.

Tiros I had a useful lifetime of 78 days (in 1302 orbits). On June 17, 1960, a stuck relay in the satellite drained the batteries; and continued operation caused general failures. During its operational lifetime, Tiros I provided 22,952 pictures of the earth's cloud cover, of which an estimated 60 percent were of meteorological interest. Weather patterns over the earth lying roughly between 50° N and 50° S latitude were photographed. These weather

*Coleman, P. J., Jr., Sonett, C. P., Judge, D. L., and Smith, E. J., *Journal of Geophysical Research*, Vol. 65, No. 6, p. 1856, June 1960.

† Sonett, C. P., Smith, E. J., Judge, D. L., and Coleman, P. J., Jr., *Physical Review Letters*, Vol. 4, No. 4, p. 161, February 1960.

‡ Smith, E. J., Coleman, P. J., Jr., Judge, D. L., and Sonett, C. P., *Journal of Geophysical Research*, Vol. 65, No. 6, p. 1858, June 1960.

§ Coleman, P. J., Jr., Sonett, C. P., Judge, D. L., and Smith, E. J., *Journal of Geophysical Reserch*, Vol. 65, p. 1856, 1960.

‖ Sonett, C. P., Judge, D. L., Sims, A. R., and Kelso, J. M., *Journal of Geophysical Research*, Vol. 65, No. 1, p. 55, January 1960.

**Sonett, C. P., *Physical Review Letters*, Vol. 5, No. 2, p. 46, July 1960.

†† Coleman, P. J., Jr., Davis, L., Jr., and Sonett, C. P., *Physical Review Letters*, Vol. 5, No. 2, p. 43, July 1960.

‡‡ Coleman, P. J., Jr., Sonett, C. P., and Davis, L., Jr., *Journal of Geophysical Research*, Vol. 66, No. 7, p. 2043, July 1961.

§§ McGuire, J. B., Spangler, E. R., and Wong, L., *Scientific American*, Vol. 204, No. 4, p. 64, April 1961.

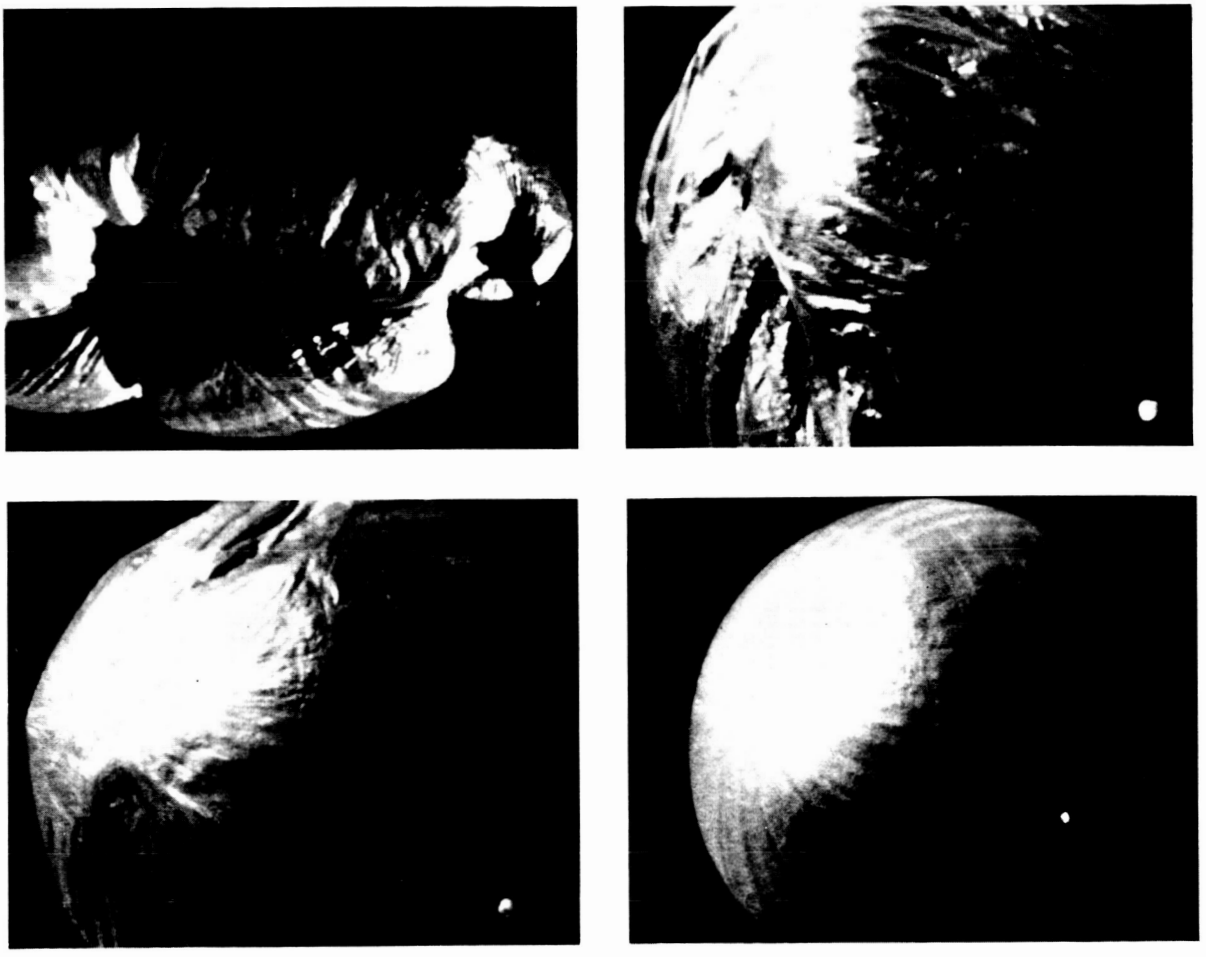
patterns, compared with data provided by conventional observations, showed that the satellite data provided more complete and more accurate information than had been possible in the past.

Studies of Tiros I pictures indicate that distinct cloud vortex characteristics are probably associated with individual storm types. Striking patterns of large spiral cloud formations, some as much as 1550 miles (2500 km) in diameter, were observed. Jet streams, thunderstorms, fronts, and regions of moist and dry air were discernible in some photographs. In the absence of obscuring clouds, large ice packs were sometimes seen.

Echo I (1960ι1)

Echo I was a 30-meter-diameter, aluminized plastic inflatable sphere that was placed into orbit on August 12, 1960. The initial orbital parameters were: period, 110.3 minutes; inclination, 47.2 degrees; perigee, 945 miles (1522 km); apogee, 1049 miles (1689 km). The Mylar polyester sphere, including subliming powders, weighed approximately 150 pounds (68 kg). Initial inflation was accomplished by the expansion of residual entrained air when the packaged sphere was ejected from the payload. Inflation was maintained by the use of subliming chemicals. The sphere carried two 10-milliwatt tracking beacons, powered by chemical batteries and solar cells.

The specific objectives of the launch were: to orbit a 100-foot-diameter, alumnized plastic sphere to be used as a passive reflector of electromagnetic waves; to study the effects of the space environment on large area-to-mass-ratio structures; to measure the reflective character-



Echo inflation test sequence.

istics of the sphere and the electromagnetic propagation characteristics of space; and to conduct experiments to determine the feasibility of using such satellites as passive relays in worldwide communication systems.

The principal communications experiments were conducted by the Jet Propulsion Laboratory (JPL) station at Goldstone, Calif.; the Bell Telephone Laboratory (BTL) station, Holmdel, N.J.; and the Naval Research Laboratory (NRL) station, Stump Neck, Md. Goldstone and Holmdel carried out the first communication experiment; JPL transmitted at 2390 Mc and received at 960.05 Mc; at the other end of the link, BTL received at 2390 Mc and transmitted at 960.5 Mc. Voice messages were transmitted over the two-way link utilizing wideband frequency modulation with special demodulation techniques developed by BTL. NRL received JPL transmissions at 2390 Mc and transmitted at either 2390 or 2390.4 Mc, using 2390 Mc when JPL was not transmitting and 2390.4 Mc for differentiation from JPL transmissions when JPL was transmitting simultaneously. In addition to experimenting with voice modulation, tests were made with continuous wave "sine wave" modulation, etc., to provide further data for evaluation of the characteristics of the passive satellite transmission media. At a secondary priority on later passes of the satellite, experiments were conducted utilizing narrow-band phase modulation, narrow-band frequency modulation, and single sideband.

Immediately after launch, and for a few days thereafter, beacon function was completely satisfactory. Suitable orbital elements were determined; and the highly directional antennas at NRL, JPL, and BTL were directed at the satellite to well within the required accuracies of 0.2, 0.2, and 0.4 degree, respectively. After a period of time, orbital data points became increasingly uncertain because of several causes. The first of these was the failure of the battery system, which limited beacon power to that supplied directly by the solar cells. Consequently, the beacons could function only when the satellite was in sunlight. A secondary cause was the progressive darkening of the epoxy resin with which the solar cells were coated. This darkening was a design feature which would cause the cells to become inactive within a period of approximately 6 months to 1 year, so that beacon transmissions would eventually cease. Finally, Echo I had changed its aspect with relation to the sun so that it passed through the earth's penumbra for more extended periods. This development precluded beacon function, and the Minitrack orbital data were based on fewer data points with a consequent loss of accuracy. Antenna-pointing accuracy requirements no longer could be met. The Minitrack network stopped tracking Echo I on December 28, 1960.

Theory indicates that solar pressure affects orbital elements. Orbital eccentricity, which produces a change in perigee height, is primarily affected. The time when the satellite structure will actually reenter the earth's dense atmosphere is not precisely predictable. Such a prediction is dependent on several intangible but important factors. Most significant among these are: (1) solar pressure, (2) atmospheric pressure, (3) effective cross-sectional area, (4) mass, and (5) orbital parameters. Each of these factors is dynamic in character and dependent on the others. Should perigee decrease to less than an estimated 474.3 miles (765 km), atmospheric drag would increase markedly. As a result, the perigee would decrease in an exponential manner, causing a relatively fast reentry.

As predicted, Echo I survived the initial minimal perigee. It survived the second such period about January 1962. Predictions beyond this point are dependent on continued observations of the orbital elements.

The communication path losses via the satellite during the early weeks agreed well with theoretical values. Immediately on coming out of the tenth (August 25, 1960) eclipse with the earth, a small microwave scintillation was first observed; its amplitude was about 2 decibels peak-to-peak about the initial level of -1 decibel. The magnitude of scintillations has gradually increased. At present, they are sometimes 10 to 15 decibels in amplitude, with occasional fluctuations of 20 to 30 decibels. Since there is only about a 25-decibel safety margin in the communications path, it is apparent that the

signal drops below the receiver threshold for brief periods. For these reasons, the communications path now may be considered submarginal. The average value of the fluctuation signals returned from the satellite are about 3 decibels below the initial levels. Calculations indicate a reduction in the average cross sectional area of one-half of the original value. This corresponds to an average equivalent diameter of about 75 feet.

Very significant information has been gained from Project Echo. It may be summarized as follows:

1. The use of a sphere as a passive reflector has been effectively demonstrated. System and space transmission losses do not differ substantially from those anticipated.

2. With good reflector sphericity there is no appreciable cross-polarization of reflected signals. However, as wrinkling occurs, there are increasing cross-polarized signal components. Further analysis is required in this area. So far there has been no bar to the adequate use of Echo I because of excess polarization.

3. The uniquely large area-to-mass ratio of Echo I has made it possible to determine the effect of solar pressure on its motion, and a quantitative measure of such effects has been applied to orbit predictions.

4. The whole complex of tracking, determining orbits, and pointing narrow-beam antennas using computed drive tapes has been demonstrated successfully, so that a satellite can be used in synchronized fashion for communication relay between two remotely located sites.

5. Radar cross-sectional measurements have been made in the satellite. They have indicated a gradual decrease in *average area* which, presently, appears to be about one-half of the original value.

6. The lifetime of the balloon as a sphere or near-sphere has been surprisingly long, refuting early calculations and estimates of collapse in the earth's shadow and suggesting that balloon tension or electrostatic forces act more favorably than anticipated.

Explorer VIII (1960ξ1)

This satellite was launched on November 3, 1960, with the objective of studying the temporal and spatial distribution of ionospheric parameters by direct measurement. The 90-pound satellite was launched into an orbit of 50-degree inclination with a 258 mile (415 km) perigee and a 1423 mile (2290 km) apogee. Spin stabilization at 30 rpm was used. Data transmissions stopped on December 27, 1960, the approximate date estimated for exhaustion of the chemical batteries. No solar cells were used.

The instruments included a radio frequency (RF) impedance probe for determination of electron concentration, four ion traps for measurements of positive-ion concentration and mass distribution, two Langmuir probes for measurement of electron temperature, an electric-field meter for determination of satellite charge distribution, and two instruments for determining micrometeorite impacts. All instruments operated continuously with the exception of the electric-field meter, which operated only by command.

One of the micrometeorite detectors consisted of two microphones with a maximum detectable sensitivity of 10^{-4} dyne-second and a dynamic range of 3 decades. This detector reported frequency and momenta of impacts. The second micrometeorite detector used a photomultiplier tube with a 1000A evaporated layer of aluminum on the window. Light flashes generated by micrometeorite impacts on the aluminum are translated into pulses of varying length and amplitude by the photomultiplier. The pulses are interpretable in terms of the kinetic energy of the impinging particle. Sensitivity was estimated to be sufficient to detect particles of $< 10^{-15}$ gm having a velocity of 20 km/sec.

The radiofrequency impedance probe experiment could be applied to the antenna upon command, to study ion sheath effects.

Two of the four ion traps were single-grid models and thus sensitive to photoemission. The remaining two ion traps were multiple-grid models not sensitive to photoemission. Comparison of the data from the two experiments gives the magnitude of the photoemission current.

The Langmuir probe measured both electron and positive-ion currents. The vehicle potential can be deduced from the saturation value of the electron current.

The electric-field meter was of the rotating-shutter type and capable of measuring fields up to 10,000 volts/meter. Its noise equivalent was less than 5 volts/meter and residual drift less than 5 volts/meter.

This satellite successfully measured electron density and temperature; positive-ion mass and density; and the momentum, energy, and spatial distribution of micrometeorites.

Tiros II (1960π1)

Launched November 23, 1960, into an orbit of about 406 miles (625 km) perigee and 431 miles (730 km) apogee, Tiros II was similar to Tiros I but carried, in addition, infrared sensors to observe the radiation from the earth and its atmosphere, and a magnetic coil for partial control of orientation. The magnetic coil was included on the basis of experience with Tiros I, whose spin axis had moved in an unexpected manner (but fortunately remained more favorable for observations). These motions were caused by the interaction of an induced magnetic field in the satellite with the magnetic field of the earth. The new coil allows some control of satellite orientation and camera pointing.

Presumably resulting from a malfunction associated with the lens of the wide-angle camera, the pictures from this Tiros II camera failed to show the detail that was so striking in the Tiros I photographs. They did disclose large cloud masses or clear areas, and have proved useful in day-to-day weather analyses and forecasting. The narrow-angle camera pictures are of excellent quality.

Prior to the launching of Tiros II, 21 countries were offered the necessary orbital data if they wished to conduct special meteorological observations to be correlated with the satellite observations. Ten of the 17 countries which indicated a desire to participate chose to proceed with their programs even though the wide-angle camera picture quality proved poorer than expected.

The measurements made by the infrared detectors on Tiros II are: temperature of the top of the water vapor layer (6.3μ); surface temperatures or cloud-top temperatures (8–12μ), which help to distinguish cloudy areas at night; the amount of reflected radiation (0.2–5μ); the amount of emitted radiation (7–30μ); and low-resolution cloud pictures (0.5–0.7μ).

The magnetic orientation coil has, on several separate occasions, functioned as planned. The sensor instrumentation worked properly until mid-January, when a malfunction in the clock control system forced discontinuance of remote wide-angle pictures to reduce the danger of a power drain that would disable the entire satellite. Direct pictures are continuing. Satisfactory radiation signals also are continuing to be received, although in late January a significant degradation in the quality of the 6.3μ-channel data was noted.

The first Mercury–Redstone flight occurred December 19, 1960. In this flight, the capsule reached a peak altitude of 135 miles, a range of 225 miles, and encountered 5½ minutes of zero-gravity flight. The flight was a success. The capsule-control system, retrorockets, separation rockets, communications equipment, and recovery equipment functioned properly. The capsule was recovered soon after landing by a helicopter dispatched from an aircraft carrier.

Tracking, data acquisition, and communications for this project was a responsibility of the Goddard Space Flight Center.

Sounding Rockets

Goddard Space Flight Center successfully launched numerous instrumented sounding rockets during the period January 1, 1960, to December 31, 1960.

GSFC Sounding Rocket Flights, 1960

Vehicle*	Firing†			Project Scientist	Experiment	Results‡
	Date	Site	Performance‡			
Argo D–4						
2 T	Jan. 26	WI	S	GSFC/NRL/DRTE	X248 Vibration test	S
Aerobee 150						
1 T	Feb. 16	WI	X	Medrow	Rocket test	X
Nike-Asp						
1 S	March 1	WI	S	Hallam	Solar study	X
2 S	3	WI	S	Hallam	Solar study	X
Aerobee 150						
12 T	25	WI	S	Medrow	Rocket test	S
Aerobee 150						
10 T	April 23	WI	S	Medrow	Rocket test	S
4 G	26	WI	P	Kupperian	Stellar fluxes	P
Nike-Asp						
3 S	27	WI	X	Hallam	Solar study	X
Aerobee 150						
9 A	29	WI	S	Horowitz	Atmospheric comp.	S
Nike-Asp						
4 S	May 25	WI	X	Hallam	Solar study	X
Aerobee 150						
5 G	27	WI	S	Boggess	Stellar fluxes	P
Nike-Cajun						
17 E	June 6	FC	S	Fichtel	Solar beam experiment (SBE)	S
3 A	16	WI	P	Nordberg	Grenade	X
Aerobee 150						
6 G	24	WI	S	Boggess	Stellar fluxes	S
Argo D–4						
7 E	30	WI	X	Heppner	Magnetic field	X
Nike-Cajun						
4 A	July 8	WI	S	Nordberg	Grenade	S
1 A	13	WI	X	Nordberg	Grenade	X
18 E	21	FC	S	Fichtel	SBE	S
Iris						
1 T	22	WI	S	Sorgnit	Rocket test	S
Nike-Asp						
28 T	Aug. 9	WI	S	Sorgnit	Rocket test	S
Nike-Cajun						
19 E	Sept. 3	FC	S	Fichtel	SBE	S
20 E	3	FC	S	Fichtel	SBE	S
Aerobee 100						
3 P	15	FC	S	Baumann	Arctic meteorology photo probe (AMPP)	S
Argo D–8						
1 E	19	PMR	S	Naugel	Nuclear emulsion recovery rocket (Nerv I)	S
Aerobee 100						
5 P	24	FC	S	Baumann	AMPP	P

See footnotes at end of table.

GSFC Sounding Rocket Flights, 1960—Continued

Vehicle*	Firing†			Project Scientist	Experiment	Results‡
	Date	Site	Performance ‡			
Nike-Cajun						
21 E	Sept. 27	FC	S	Fichtel	SBE	S
Aerobee 150						
43 P	Oct. 5	FC	S	NRL—Baumann	AMPP	S
Iris 2 T	18	WI	S	Sorgnit	Rocket test	S
Nike-Asp						
29 T	Nov. 3	WI	S	Sorgnit	Rocket test	S
Nike-Cajun						
22 E	11	FC	S	Fichtel	SBE	S
23 E	11	FC	S	Fichtel	SBE	P
24 E	12	FC	S	Fichtel	SBE	S
15 E	12	FC	S	Fichtel	SBE	S
16 E	13	FC	S	Fichtel	SBE	S
Aerobee 150						
14 A	15	WI	S	Taylor	Atm. comp.	S
Nike-Cajun						
10 A	16	WI	S	Univ. of Mich.—Dubin	Atm. comp.	X
13 E	16	FC	S	Fichtel	SBE	S
14 E	17	FC	S	Fichtel	SBE	S
26 E	17	FC	S	Fichtel	SBE	S
27 E	18	FC	S	Fichtel	SBE	S
Aerobee 150						
11 S	22	WI	S	Stecher	Stellar spectra	S
Aerobee 100						
1 I	23	FC	S	Whipple	Ionosphere	S
2 I	27	FC	S	Whipple	Ionosphere	S
Argo D-4						
8 E	Dec. 12	WI	S	Heppner	Magnetic fields	S
Nike-Cajun						
6 A	14	WI	S	Nordberg	Grenade	S

*A—Aeronomy
E—Energetic particles & fields
G—Galactic astronomy
I—Ionospheric physics
P—Special projects
S—Solar physics
T—Test & support

†WI—Wallops Island, Va.
FC—Fort Churchill, Canada
PMR—Point Arguello Calif.

‡S—Successful
P—Partial success
X—Unsuccessful

Aeronomy

Mass spectrometers were used on three flights. A daytime Aerobee flight on April 29 from Wallops Island, Va., produced good quality ion data. Good results were also obtained from a flight made on November 15 from Wallops Island. Measure of positive ion content and energies have led to the calculation of scale heights between altitudes of about 217 miles (350 km) and about 434 miles (700 km).

Flight of Nike-Cajuns of July 8 and December 14 from Wallops Island, the first of a series to measure atmospheric winds and temperatures by means of the grenade technique, furnished usable data.

Launchings were made from Fort Churchill, Manitoba, to secure photogrammetric data in support of the meteorological satellite program. The objectives were: (1) to photograph a region containing a large variety of clouds, but with some identifiable ground features, to be used for photogrammetry; (2) to evaluate films for future use in high altitudes for weather photography; and (3) to test the recovery system

and evaluate it for future use in land or water recovery. All objectives were met.

Ionospheric Physics

Two Aerobee 100 rockets were launched in late November from Fort Churchill to obtain day- and night-time ion and electron densities and the electrical conductivity of the atmosphere from about 12.4 miles (20 km) to about 56.8 miles (90 km).

Energetic Particles and Fields

A Javelin rocket launched on December 12, 1960, from Wallops Island carried the first rocket-borne, rubidium-vapor magnetometer to an altitude of about 719.82 miles (1161 km). The instrument gave accurate measurements over the entire trajectory.

On September 19, 1960, a Journeyman rocket was launched from the southern coast of California out over the Pacific Ocean to an altitude of about 1178 miles (1900 km). The payload consisted of a package of recoverable nuclear emulsions for studies of the flux and composition of the particles in the inner Van Allen belt. The emulsions are being analyzed and already have shown that there is a flux of 10-Mev protons, almost an order of magnitude higher than had been predicted. Ultimately, this flight will give the differential energy spectrum at eight altitudes in the inner belt.

Fourteen Nike-Cajun rockets carrying recoverable nuclear emulsion payloads were launched from Fort Churchill during the summer and fall of 1960. Entitled the "Solar Beam Experiment," this project had the object of performing a detailed study of the high-energy particles arriving at the earth after a large solar disturbance. Seven of the rockets were launched to study the large solar flare that began on November 12, 1960. Five of these payloads were recovered in excellent condition. The remaining rockets were launched over the course of the summer to establish normal background counts, to study auroral particles, and to study a weak polar cap absorption event.

Brief descriptions of the individual flights follow.

June 6, 1960—This flight was to test out the rocket recovery system and to obtain data during a period of low solar activity. Rocket performance was excellent. The payload was recovered, and telemetry functioned.

July 21, 1960—Aurora flight made to determine what particles are present during an auroral absorption event. Telemetry worked; no recovery. Telemetry data showed 0.3 erg/cm^2 sec ster of electrons ($E \geqq 20$ kev) and a particle flux $J = 8 \times 10^3$ cm^{-2} sec^{-1} ster^{-1} of electrons ($E \geqq 150$ kev).

September 3, 1960—Rocket was launched into a polar blackout. Recovery and telemetry worked satisfactorily. Data have been partially reduced. It was shown that heavy particles ($Z \geqq 3$) come from the sun during a solar flare. The proton energy spectrum was measured down to about 1 Mev.

September 3, 1960—Objective was same as above flight. Telemetry satisfactory; no recovery.

September 27, 1960—This rocket was fired into a weak polar cap absorption event. Flux of protons was about ten times the normal cosmic ray background.

November 11, 1960—Two rockets were launched into auroral absorption events. Significant numbers of protons and electrons were present. A very steep proton spectrum was observed. Emulsions have been analyzed.

November 12, 1960—This was the first rocket launched into the major polar cap absorption event caused by flares on November 10 and 12. This firing provided the first detailed data on the flux, composition, and energy spectrum of a major solar proton beam.

November 12, 1960—This rocket was launched at peak intensity of the solar event. Telemetry satisfactory, but no recovery.

November 13, 1960—Another launching made during above event. Telemetry and recovery satisfactory.

November 16, 1960—A rocket was launched after the event had reached its peak. Recovery and telemetry satisfactory.

November 17, 1960—This rocket was launched at midnight local time to study flux at night when riometer shows minimum.

November 17, 1960—The sixth rocket launched during this event was to study time changes in the flux, energy spectrum, and composition. Recovery and telemetry satisfactory.

November 18, 1960—This was the last rocket launched during this event. The solar flux was in final phase, characterized by low flux and few—if any—high-energy particles. Recovery and telemetry satisfactory.

Astronomy

An Aerobee 150A was launched on May 27 from Wallops Island, Va., carrying a payload designed to measure stellar fluxes at 2700A, 2600A, and 2200A and to map and make intensity measurements of ultraviolet nebulosities at 1300A and 1216A. The instrumentation performed well, but the rocket did not despin and the primary objective was not met. High-quality airglow data were obtained, however.

A repeat flight on June 24 reached an altitude of about 130.82 miles (211 km) with satisfactory despin. Excellent data were obtained on ultraviolet-stellar fluxes, including the first unambiguous recorded signal from a star at 1300A. Information was also obtained on the nighttime ozone distribution and on the height of the ultraviolet airglow.

On November 22, 1960, an Aerobee 150A was launched from Wallops Island carrying instrumentation to measure the intensity distribution of stellar spectra with 50A and 100A resolution in the wavelength region 1300A to 4000A. Spectra were obtained with 50A resolution for a number of stars of varying spectral types over the 1700A to 4000A region.

Rockets launched during the International Rocket Interval September 13 to 22, 1960, included the high-altitude nuclear emulsion recoverable payload (Nerv) and one of the arctic-cloud-cover photography experiments.

SUMMARY OF ACTIVITIES AND RESULTS FOR 1961

New Results From Earlier Launches*

The year 1961 saw published in finished form scientific results for which only preliminary announcements had been released on the basis of the rapid scanning of limited data. In the present summary, any fuller and later reports that did not significantly change the earlier announcements have been neglected.

*Source: "United States Space Science Program," prepared by the Space Science Board of the National Academy of Sciences, National Research Council, submitted to the Committee on Space Research (COSPAR), Washington, D.C., May 1, 1962.

Tiros I

Processing and research utilization of the nearly 23,000 Tiros I cloud pictures has continued. In early July, positive and negative 35-mm rolls of the ungridded Tiros I pictures were placed on sale by the National Weather Records Center, Asheville, N.C.

Tiros II

The operation of Tiros II continued during most of 1961, but with a more or less progressive deterioration in the quality of data obtained. The blackbody sensor of the wide-angle radiometer failed in March. Of the scanning radiometer channels, the 6.3μ channel had degraded early in the year, the 7 to 30μ channel in early April; and no useful infrared data were obtained after April 23, 1961. The infrared electronics and tape recorder continued to function, however, until the satellite was shut off in early December after more than a year in orbit. Except for temporary suspensions, the cameras had been programmed to operate regularly until the Tiros III launch on July 12, 1961, and from then until August 8, 1961, on an average of two orbits per day. Cloud pictures of operationally significant meteorological value were obtained in early August. After August 8, camera programming was on a sporadic basis because of power limitations. The last pictures obtained, in November 1961, were still not completely useless although of obviously degraded quality. A total of 36,156 pictures was obtained.

The third pair of spin-up rockets was fired with partial success in mid-September 1961. The fourth pair was successfully fired on September 28 after more than 10 months in orbit. The magnetic orientation coil worked well until late November 1961. In early December 1961, the satellite no longer appeared to be responding to orientation coil commands and was so oriented that the sun shining on the base plate produced excessive heating and very little power. The beacons were shut off on December 3, 1961. Although research analysis and utilization of the Tiros II infrared data are still only in early states, specific case studies have

clearly demonstrated the expected correlation between the 8 to 12μ atmospheric window data and the concurrent patterns of cloud cover and cloud top altitude.

During the fall of 1961, a *Tiros II Radiation Data User's Manual* was published, along with volume I of the *Tiros II Radiation Catalog*. Volume I of this catalog contains analyzed grid point data for fifty orbits of the Tiros II scanning radiometer data.*

Perhaps the most striking of the Tiros II picture data were several examples of narrow-angle camera photographs of sea ice in the area of the Gulf of the St. Lawrence. One series of such examples was obtained in January 1961; the second in late March. The March pictures included coverage from the Gaspé Peninsula to east of Newfoundland and show significant changes in the ice patterns, particularly in the vicinity of Anticosti Island.

Echo I

Echo I provided data for air drag in the upper atmosphere at the altitude of its orbit. This belief has been substantiated. Thirty-fold diurnal changes in density in the upper atmosphere at the altitude of about 620 miles (1000 km), and the changes produced by solar disturbances on high-altitude atmospheric density, have been reported in the past year. The density of the atmosphere at the altitude of the Echo I orbit has been calculated from the drag and is reported as about 10^{-17} at about 620 miles (1000 km) altitude and about 10^{-18} at about 992 miles (1600 km) altitude. In another investigation, the periodic effect of solar radiation pressure on the motion of Echo I could be easily observed because of its large area-to-mass ratio.

An interesting use has been made of observations of Echo I to acquire information on the ozone distribution in the atmosphere. An experimenter reported that he found a maximum of ozone content to exist between 12.4 miles (20 km) and 18.6 miles (30 km) altitude, with the number of molecules per cubic centimeter as 2×10^{12}/cm^3 and decreasing to 10^{11} molecules/cm^3 at the altitude of 40.3 miles (65 km). Another experimenter reported that he had used a special radar tracking technique to search for ionization surrounding Echo I but that he found no evidence of such ionization in the case of either Echo I or Sputnik III (1958 δ). the reflective cross-sectional area of Echo I is measured periodically by radar; the average cross section is approximately that of a perfect sphere 15 meters in diameter.

Explorer VIII

The satellite, as mentioned before, was launched on November 3, 1960, with the objective of studying the temporal and spatial distribution of ionospheric parameters by direct observation. It transmitted data until December 27, 1960. Explorer VIII data have disclosed a number of interesting discoveries, which were reported in 1961. It measured the diurnal electron temperatures between altitudes of 244 miles (400 km) and 1364 miles (2200 km), and found the daytime temperature to be about 1800° K and the nighttime temperature to be about 1000° K. In its orbit it measured an electron concentration of 1.3×10^4 electrons/cm^3. Its ion probe reported the mean mass of the ions as 16 atomic mass units, indicating the predominance of atomic oxygen in the ions. The ion density profile determined by Explorer VIII up to 465 miles (750 km) was similar to that determined before but, in addition, showed the atmosphere to be isothermal. Another interesting and important result found by Explorer VIII was the ratio of helium to hydrogen ions. Above 496 miles (800 km) the helium ion was found to be an important constituent of the ionosphere, and at the altitude of 1364 miles (2200 km) there was a heavy predominance of helium ions over hydrogen ions. This discovery explains the high densities reported by Echo I in its high-altitude orbit. The instruments carried by Explorer VIII also revealed the spacecraft to be charged and, as the altitude of the craft increased, the negative charge changed to positive.

Satellites Launched in 1961

The following Goddard-managed satellite launches took place in 1961.

*The *Manual*, the *Catalog*, and copies of the magnetic tape data tabulations for these fifty orbits are available from the National Weather Records Center.

Echo prototypes.

Explorer IX (1961δ1)

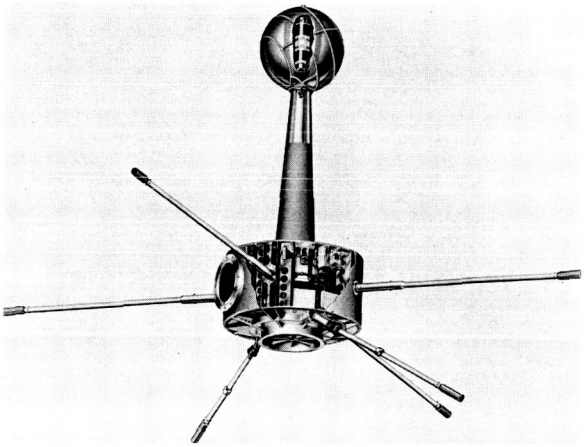
Explorer IX, a 12-foot inflatable sphere made of Mylar and aluminum foil, weighed 15 pounds. It was launched on February 16, 1961, for the purpose of obtaining atmospheric densities from drag measurements and went into orbit with a perigee of 395 miles, an apogee of 1605 miles, and an inclination of 39 degrees. The tracking beacon carried by the sphere failed to operate after the sphere was placed in orbit, but optical tracking from the ground was successful. By means of this satellite, density of the atomosphere at an altitude of 434 miles was calculated from drag for comparison with values calcuated from Echo I at about twice this altitude. The sphere was sensitive to changes in the density along relatively small segments of its orbit and was thus able to reveal the effect of solar disturbances on upper-atmosphere density.

The results obtained by Explorer IX, combined with those of Echo I and other satellites such as Vanguard I, showed that the upper atmosphere is a dynamic region of changing density caused by the diurnal variation of sunlight and by the smaller changes of energy associated with solar disturbances.

Explorer X (1961κ)

This spin-stabilized earth satellite, weighing about 79 pounds, was launched on March 25, 1961, into a highly eccentric orbit with an apogee of about 186,000 miles located at an angle of 140 to 150 degrees from the sun-earth line, and a perigee of about 100 miles.

The highly eccentric orbit was selected for the purpose of studying the properties of the magnetic field and the solar-interplanetary plasma over a region extending from close to the earth out to a point where the effects of the earth's



Explorer X, an interplanetary probe, launched March 25, 1961.

magnetic field should be negligible. The scientific payload consisted of an extremely sensitive rubidium-vapor magnetometer, two flux-gate saturable-core magnetometers to measure the spatial and temporal variations of the geomagnetic and interplanetary fields, and a multi-grid plasma probe to determine the flux, energy spectrum, and directionality of very low energy protons in the plasma. Since the satellite was spin-stabilized, a sun sensor was used to provide information about the orientation of the instruments relative to the sun. Power to the satellite was provided by batteries having an active life of about 60 hours, sufficient to permit continuous measurements to be made on the first outward pass to apogee.

Quiet magnetic conditions prevailed prior to and during the first day of the satellite's outward pass to apogee; solar activity was confined to Class 1 and 1− flares. However, at 10:15 UT on the second day after launch, a Class 3 flare occurred near the east limb of the sun, producing disturbed magnetic conditions in the vicinity of the satellite and at the earth.

Although detailed analysis of the data obtained is still being carried out, the experimenters have reported significant findings:

*Magnetic Fields**—The measured geomagnetic field between 1.8 and 5 earth radii over the South Atlantic Ocean was found to be less than the computed field.† The discrepancy was attributed to the existence of a field source having its maximum strength at an altitude between 1.8 and 3 earth radii at the geomagnetic equator. From 5 to 6.6 earth radii, the measured geomagnetic field was in agreement with the computed field. Superposition of the earth's field and the interplanetary field was detected between 11 and 19 earth radii. Beyond 19 earth radii the earth's field was negligible.

The interplanetary field between 20 and 21.5 earth radii was found to be stable. However, its intensity was more intense than anticipated. The field was approximately radial from the sun. An abrupt change in the character of the interplanetary field was detected simultaneously with the first detection of the solar interplanetary plasma at 21.5 earth radii. Large fluctuations both in magnitude and direction were encountered for 5 hours after the onset of the abrupt change and were attributed to the passage of shock waves.

When the satellite was at 37.1 earth radii, an increase in the interplanetary field intensity occurred at about the same time that a sudden commencement was observed at the earth's surface, indicating that little if any delay was associated with the arrival of the sudden commencement disturbance at the earth's surface from outside the earth's field.

Solar–Interplanetary Plasma—The Explorer X satellite provided the first experimental observation of a plasma in interplanetary space.‡ A strongly spin-modulated signal was present at all energies near the earth, from 1.3 to 2.9 earth radii. The interplanetary plasma was first detected at 21 earth radii, and its presence was confirmed out to 38.5 earth radii.

Correlation of the plasma data with the magnetic field data indicated that the presence of the plasma was coincident with a relatively weak field which fluctuated in magnitude and direction. Absence of a plasma was associated with strong steady fields directed away from

*Heppner, J. P., Ness, N. F., Skillman, T. L., and Scearce, C. S., *Goddard Space Flight Center Contributions to 1961 Kyoto Conference on Cosmic Rays and the Earth Storm*, 1961.

†Finch, H. F., and Leaton, B. R., *Monthly Notices Roy. Astron. Soc., Geophys. Suppl.*, Vol. 7, No. 6, p. 314, November 1957.

‡ Bridge, H. S., Dilworth, C., Lazarus, A. J., Lyon, E. F., Rossi, B., and Scherb, F. (Massachusetts Institute of Technology), "Plasma Measurements from Explorer X," presented at *1961 Kyoto Conference on Cosmic Rays and the Earth Storm.*

the sun. Large fluctuations in plasma intensity were detected between a minimum detectable value of less than 5×10^6 and about 10^{10}/cm^2/sec[1].

The energy spectrum of the positive particles was found to be peaked at 500 electron volts even though the shape of the energy spectrum showed large variations. The number density of the plasma protons ranged from 6 to 20 cm^3.

The plasma arrived from the general direction of the sun.

Explorer XI (1961ν1)

Explorer XI, the gamma-ray astronomy satellite, was launched on April 27, 1961, into an orbit with an inclination of 28.8 degrees, a perigee of 304 miles, and an apogee of 1113.2 miles. Its period was 108.1 minutes. The objective of this satellite was the detection of extraterrestrial high-energy gamma rays, such as result from the decay of neutral π mesons. The experiment was designed to detect and map the direction and intensity of the galactic gamma rays above the earth's atmosphere. Earlier balloon experiments had been limited by the background radiation produced in the residual atmosphere.

Explorer XI resembled an old-fashioned street lamp with the payload constituting the lamp and the attached burned-out fourth stage the post. Before being put into orbit, the payload and the fourth stage were spun about the longitudinal axis at 6 cps, but the whipping of the external loop antennas and the nutation damper included in the satellite converted the rotation into an end-to-end tumbling that was desired for scanning the entire sky. Storage batteries carried the major portion of the power load.

The instrumentation consisted of a gamma-ray telescope and sensing devices in the forward end of the payload. The latter reported the position of the satellite relative to the earth's horizon and to the sun. The telescope consisted of a sandwich of scintillation crystals and of a Cerenkov detector contained in an anticoincidence shield. The use of crystals with different fluorescent decay rates—namely, CsI(Tl) and NaI(Tl)—permitted differentiation between gamma rays and neutrons. When the instrumentation was not in the anticoincident mode, primary cosmic-ray protons could be observed. These particles are known energy and can be used as a calibration standard for the energy of the gamma rays.

The aluminum housing of the satellite, serving as a micrometeorite shield, emitted secondary neutrons and gamma rays, the background counts from which could obscure the results if the intensity of celestial gamma rays was low.

Explorer XI achieved too high an apogee and consequently reached into the inner Van Allen belt, which masked the gamma-ray counts in that portion of the orbit. As a result, useful data were supplied only about 5 percent of the time in orbit. Preliminary results of the analysis of these data have been given by the Massachusetts Institute of Technology, based on some 23 hours of useful observing time in a period of 23 days.

During this period 127 events which could have been gamma rays occurred. Of these, 105 were shown by analysis to have come from the direction of the earth and were presumably produced in the earth's atmosphere; the remaining 22 came from a variety of directions. The analysis of arrival directions was complicated by the fact that all portions of the sky were not scanned for the same length of time. Therefore, use was made of an idealized model of the galaxy. It was assumed to be a disk 100,000 light years in diameter and 1000 light years in thickness, filled uniformly with a gas of one hydrogen atom per cubic centimeter, having a cosmic-ray density equal to its value in the vicinity of the earth. By means of this model, "predicted" intensities were used to evaluate an expected number of counts in each of the cells into which the sky was divided. Comparison of the "predictions" with the observations showed a good degree of consistency with regard to spatial distribution and to the number of events. The results are consistent with a source strength of gamma rays in the galaxy of the order of 10^{-24}cm^{-3}sec^{-1}.

Tiros III (1961ρ1)

This satellite was launched on July 12, 1961, into an orbit with a 48.2-degree inclination, an apogee of 506.44 miles, and a perigee of 461.02 miles. Both TV cameras were of the wide-angle type. Tiros III was basically the same as Tiros

II except that a third set of infrared sensors, developed by V. Suomi of the University of Wisconsin, was added; these sensors, very much like his experiment on Explorer VII, consisted of two pairs of hemispheres (each pair consisting of one black and one white hemisphere), mounted on mirrors, on opposite sides of the spacecraft.

The satellite was commanded from, and data were acquired at, stations located on St. Nicholas Island, Calif., and Wallops Island, Va. An auxiliary command (only) station at Santiago, Chile, permitted obtaining more hurricane and other cloud picture data over the tropical Atlantic Ocean than would otherwise have been possible.

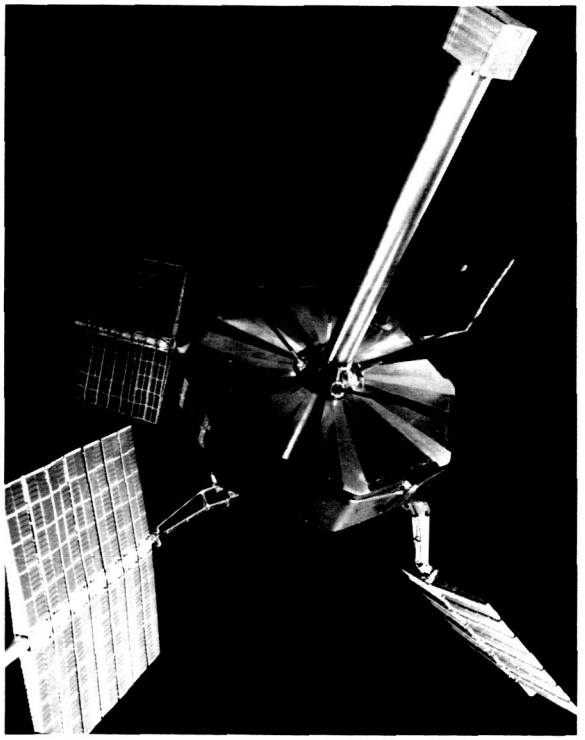
Tiros III has proved a worthy successor to the earlier satellites in the series, especially with regard to the discovery and tracking of Atlantic hurricanes and Pacific typhoons. The cloud-picture data from these and other weather situations were made available for operational weather analysis and forecasting through internationally disseminated operational nephanalyses.

On more than 50 separate occasions, Tiros III photographed tropical cyclones in all stages of development. Five hurricanes (Anna through Esther, inclusive) and one tropical storm were seen in the Atlantic; two hurricanes and a tropical storm were seen in the data-sparse region of the Pacific of Baja, Calif. Typhoons Kathy through Tilda, nine storms in all, were followed in the central and western Pacific.

On a single day (September 11, 1961), Tiros III photographed Hurricanes Betsy (in a dissipating stage), Carla (as it hit the Texas coast), and Debbie; discovered the tropical storm later designated as Hurricane Esther; and photographed Typhoons Nancy and Pamela.

One of the two Tiros III cameras ceased operation on July 27, 1961, apparently because of a stuck shutter, confirming the desirability of redundant wide-angle cameras. Some deterioration of the quality of the TV pictures of the second camera was noted as early as the second week in August, and became progressively worse from then on. Routine preparation of operational nephanalyses was stopped in late November 1961, when the picture quality became too poor. Few nephanalyses were transmitted after that date, and archiving of the pictures was terminated. The tape recorder on the second camera ceased to function on December 5, 1961, preventing further data acquisition in remote mode. It was possible to resume direct picture taking in early January 1962, but quality remained poor and the pictures were of little, if any, practical value. Over 35,000 pictures were obtained through the end of December 1961.

Degradation of the 6.3μ and 7 to 30μ infrared channels was noted as early as August 5, 1961. No useful infrared data were obtained after October 30, 1961; for several weeks before then, about 50 percent of the data were lost because of problems with the tape recorder playback mechanism.



Explorer XII, an energetic particles satellite, launched August 15, 1961.

Explorer XII (1961υ1)

Explorer XII, the energetic particles satellite, was launched on August 15, 1961, in an orbit with a perigee of 180 miles, an apogee of

47,800 miles, and an inclination of 33 degrees. The highly eccentric orbit permitted measurements both in interplanetary space and inside the earth's magnetosphere. About 90 percent of the time of the satellite was spent in the Van Allen belt region. The objectives of this satellite were to describe the protons and electrons trapped in the Van Allen radiation belts; to study the particles coming from the sun, including the occasional very intense bursts of high energy protons which present a hazard to manned flight; to study the cosmic radiation from outside the solar system; and to correlate particle phenomena with the observed magnetic field in space about the earth. Although Explorer XII had been expected to supply useful data for a period of one year, it ceased reporting on December 6, 1961.

Explorer XII was octagonal in shape, 19 inches from side to side, and 27 inches long including a magnetometer boom. It carried four laterally extended paddles, carrying solar cells. Prior to injection into orbit, the satellite and third stage were spun to 150 rpm for stabilization. After burnout of the third stage, a yo-yo despin device slowed the rate down to 31 rpm. Further despinning to 18 rpm occurred as the solar paddles were extended just prior to separation of the spacecraft from the third stage.

Seven experiments were carried in the satellite:

1. A proton analyzer was used to measure the proton flux and distribution of energies in the space beyond 6 earth radii. Although the mass of the particles was not measured, the particles were assumed to be protons, since the latter probably constitute at least 85 percent of the positive-ion population in space.

2. A three-core flux-gate magnetometer, sensitive to a few gammas, was used to measure the earth's vector magnetic field at distances of 3 to 10 radii.

3. The trapped-radiation experiment (four Geiger counters and three CdS cells) measured the fluxes and energies of particles emitted by the sun and galactic cosmic rays, as well as trapped Van Allen belt particles.

4. The cosmic-ray experiment monitored cosmic rays beyond the effect of the earth's magnetic field during the apogee portion of the orbit. The instrumentation consisted of a double telescope for cosmic rays, a single crystal detector of energetic particles, and a Geiger–Mueller telescope for cosmic rays. The group of instruments was capable of obtaining data on the flux of moderate to very energetic protons 1 to 700 Mev, on the flux of low-energy alpha particles, and on the differential spectrum of proton energy.

5. An ion-electron detector was carried to measure particle fluxes, types, and energies in and above the Van Allen belts. This device consisted of a photomultiplier tube coated with a powder phosphor, ZnS(Ag), in combination with absorbing screens for the detection of energetic particles and with a scattering block for the detection of electrons. The energy flux could be measured for protons with energies below 1 Mev and for electrons below 100 kev.

6. An experiment was carried to determine the deterioration of solar cells resulting from direct exposure to the radiation in the Van Allen belts, and to compare the effectiveness of glass filters in preventing degradation of solar cells.

7. An optical aspect experiment was carried to determine the orientation in space of the spacecraft as a function of time. Six photodiodes gave the position of the spin axis of the satellite relative to the sun's elevation with an accuracy of about 5 degrees in azimuth and elevation.

The launch occurred as planned, and all experiments functioned normally until December 6, 1961, when the satellite ceased transmitting; telemetry coverage of nearly 100 percent was maintained until then. By September 12 the spin rate of the satellite had increased from the initial value of 27.8 rpm to 28.63 rpm as a result of the solar-radiation pressure on the solar cell paddles. The unprotected cells in the solar cell experiment suffered a major degradation when the spacecraft passed through a point of high proton concentration in the Van Allen belts. Degradation for the test cell patches covered by glass was not noticeable.

The instrumentation carried in this satellite indicated that the level of electron flux in the outer Van Allen belt was about three orders

lower than what had previously been considered to be present. The ion-electron detector, which was capable of measuring protons of low energy, showed that protons are present in the outer Van Allen belt, which had at one time been believed to be populated only by electrons. The instrumentation on board this satellite detected electrons out to a boundary at 8 earth radii, with a maximum flux at 6 to 7 earth radii.

Explorer XIII (1961X1)

The effects of micrometeoroids or cosmic dust in collisions with spacecraft, and the likelihood of collisions, are unknown, but the possibility that the particles constitute a hazard to travel in the space environment is very real and must be investigated. The micrometeoroid satellite, Explorer XIII, was designed to provide an improved estimate of the danger of penetration of spacecraft by cosmic dust by securing direct measurements of the puncture hazards in spacecraft structural skin specimens at satellite altitudes. In addition, the satellite carried instruments to measure micrometeorite flux rates and to obtain data regarding the erosion of spacecraft materials.

The satellite was launched on August 25, 1961, but failed to obtain a high enough perigee. All the data collected during its 2½ days of life were telemetered during 13 minutes of time.

Explorer XIII carried a group of experiments installed around the fourth stage of a Scout launcher. The satellite was cylindrical in shape, 76 inches in length, and 24 inches in diameter; the overall weight was about 187 pounds. Five types of detectors were carried. One consisted of a battery of pressurized cells in which the presure was released upon puncture. In the second type, foil gauges showed impact of micrometeorites by a change in resistance. A third type of experiment showed a change of resistance in wire grids when a wire was broken by impact. Another detector used CdS photoelectric cells which detected the light transmitted through the eroded holes in aluminized Mylar sheets. The fifth experiment recorded impacts on piezoelectric crystals.

The satellite was spin-stabilized during the last stage of burning. It was expected that interaction of the satellite with the magnetic field of the earth would cause the original spin to turn into a tumbling motion after 10 days. Two separate telemeters were used for storing and telemetering data. Both used Goddard's Minitrack telemetry and coding system.

Sounding Rockets Launched in 1961

Goddard Space Flight Center successfully launched 69 sounding rockets carrying scientific instrumentation during the period January 1, 1961, to December 31, 1961. Degree of success breakdown is at follows:

49—Successful
7—Qualified success
3—Failure directly attributable to rocket
8—Failure of experiment
2—Failure to recover where total experiment depended on recovery

GSFC Sounding Rocket Flights, 1961

Vehicle*	Firing					Project Scientist	Experiment	Result‡
	Date	Time (Z)	Altitude (Stat. miles)	Site†	Performance‡			
Nike-Asp								
36 T	Jan. 17	2126	130	WI	S	Sorgnit	Rocket test	S
Iris 3 T	19	1242	86	WI	X	Sorgnit	Rocket test	P
Nike-Cajun								
7 A	Feb. 14	2350	81	WI	S	Nordberg	Grenade	S
8 A	16	0226	52. 8	WI	P	Nordberg	Grenade	S
Nike-Cajun								
49 T	March 15	1747	80	WI	S	Sorgnit	Cajun fin test	S
Aerobee 150								
34 S	30	0250	45	WI	P	Boggess	Stellar fluxes	P
Nike-Cajun								
33 A	April 5	1257	71	WI	S	Nordberg	Grenade	P
Aerobee 150								
19 T	14	1715	128	WI	S	Russell	Attitude control	P
Nike-Asp								
5 A	19	0936	102	WI	S	Geophysics Corp. of America (GCA)—Dubin	Sodium vapor	S
6 A	20	2312	112	WI	S	GCA—Dubin	Sodium vapor	S
7 A	21	0934	14	WI	X	GCA—Dubin	Sodium vapor	X
8 A	21	0939	102	WI	S	GCA—Dubin	Sodium vapor	S
Argo D–4								
10 I	27	2002	472	WI	S	Jackson	Ionosphere	P
Nike-Cajun	27	2232	10. 9	WI	X	Smith	Grenade	X
34 A								
Spec. Proj.	May 2	2115	8. 5	WI	S	U. of Mich.—Spencer	Cone test	S
Nike-Cajun								
2 A	5	2300	70	WI	S	Smith	Grenade	S
28 A	5	0454	71	WI	S	Smith	Grenade	S
29 A	9	1153	72	WI	S	Smith	Grenade	P
Aerobee 100								
4 P	17	1921	47. 5	FC	S	Baumann	AMPP	P
6 P	19	1903	45. 4	FC	S	Baumann	AMPP	S

Nike-Apache									
1 T		25	1703	120	WI	S	Sorgnit	Rocket test	S
Argo D–4									
9 T	June	13	0512	539	WI	S	Jackson	Ionosphere	P
13 II		14	0002	561	WI	S	DRTE/Jackson	Antenna test	S
Aerobee 150									
20 T		26	1515	116	WI	S	Russell	Attitude control	P
Nike-Cajun									
30 A	July	13	2207	74	WI	S	Smith	Grenade	S
31 A		14	1602	63	WI	S	Smith	Grenade	S
32 A		20	1030	80	WI	S	Smith	Grenade	S
35 A		20	0350	43. 5	WI	S	Smith	Grenade	X
Nike-Apache									
2 T	Aug.	16	2027	128	WI	S	Sorgnit	Rocket test	S
Nike-Cajun									
36 A	Sept.	16	0455	55	WI	P	Smith	Grenade	P
37 A		17	1013	58	WI	S	Smith	Grenade	X
Skylark									
1 G		18	1215	120	AUS	S	Boggess	Stellar photo.	S
Aerobee 100									
8 A		23	1827	52	FC	S	Varian—Martin	Atm. structure	S
9 A		30	2042	45	FC	S	Varian—Martin	Atm. structure	S
Aerobee 150									
26 S		30	1430	139	WI	S	Behring	Solar studies	S
Skylark									
2 G	Oct.	4	1119	121	AUS	S	Boggess	Stellar photo.	S
Argo D–4									
23 A		10	1740	585	WI	S	Taylor	Ionosphere	S
Aerobee 100									
10 A		15	1433	46. 6	FC	S	Varian—Martin	Atm. structure	S
7 A		17	2012	40. 5	FC	S	Varian—Martin	Atm. structure	S

See footnotes at end of table.

GSFC Sounding Rocket Flights, 1961—Continued

Vehicle*	Firing					Project Scientist	Experiment	Result‡
	Date	Time (Z)	Altitude (Stat. miles)	Site†	Perform-ance‡			
Skylark 3 G	Nov. 1	1756	120	AUS	S	Boggess	Stellar photo.	P
Aerobee 100 11 A	2	1728	42. 4	FC	S	Varian—Martin	Atm. structure	S
12 A	5	2011	44. 3	FC	S	Varian—Martin	Atm. structure	S
Argo D–8 4 B	15	1450	1159	Pt. A	S	Campbell	Biological investigation of space (Bios I)	X
5 B	18	1343	Unknown	Pt. A	P	Campbell	(Bios I)	X
Skylark 4 G	20	1804	130	AUS	S	Boggess	Stellar photo.	S
Nike-Cajun 76 E	Dec. 10	1701	82	FC	S	Ogilvie—Fichtel	Cosmic ray	S
64 A	21	1954	82	WI	S	U. of Mich.—Spencer	Atm. structure	S
74 I	21	2131	62	WI	S	Kane	Ionosphere	S

*A—Aeronomy
E—Energetic particles & fields
G—Galactic astronomy
I—Ionospheric physics
P—Special projects
S—Solar physics
T—Test & support

†WI—Wallops Island, Va.
FC—Fort Churchill, Canada
PtA—Point Arguello, Calif.

‡S—Successful
P—Partial success
X—Unsuccessful

Electron Density Profile Probe

An electron density profile probe (P–21) was launched on October 19, 1961, from Wallops Island by means of a Scout rocket in a nearly vertical trajectory. The achieved altitude was 4261 miles. The payload itself was in the form of an eight-sided frustrum and weighed 94 pounds. The heat shield had been selected for low electrical conductivity, to permit an attempt to use the stored antennas during the propulsion period.

The flight of the probe was about 2 hours duration. It was launched near midday at a time when the ionosphere appeared quiet. The payload was spin-stablized about its axis before fourth-stage separation. Telemetry of the swept-frequency RF probe data made use of the 73.6-Mc frequency. The instrumentation carried consisted of: (1) a continuous-wave (CW) propagation experiment to measure the ionosphere profile; (2) an RF probe experiment to measure the ionospheric electron density, especially at altitudes above 620 miles where data are particularly scarce; and (3) a swept-frequency probe to provide information on the power absorbed by electron pressure waves. Two CW signals were transmitted from the rocket to the ground, one at 12.27 Mc and one at 73.6 Mc, controlled to an exact 6-to-1 ratio. Comparison of the two frequencies for Faraday rotation gave the columnar electron density in the path traversed by the beam; this experiment was of value only during the ascent of the rocket and only below 2480 miles. The RF probe experiment made use of the relatively new RF probe, and this particular unit had the dual purpose of providing information on electron densities in the ionosphere and information concerning the behavior of the probes themselves. It was planned to calibrate the RF probe during ascent to 2480 miles by means of the CW experiment and to use the probe measurements for the remainder of the flight. The RF probe made use of a capacitor in which the dielectric constant of the gas between the plates was affected by the ionization of the gas. Comparison of the capacity of the probe when in the ionosphere and when outside supplied the information necessary to determine electron density in the ionosphere. The swept frequency probe was a parallel-plate condenser exposed to the ionosphere. An RF voltage of constant amplitude was supplied to the capacitor and was varied over the frequency range from 1 to 10 Mc. The changes in reactive and resistive loading during the frequency sweep were used to calculate the electron density in the capacitor and to obtain a value for the energy absorbed in the gas as a function of frequency.

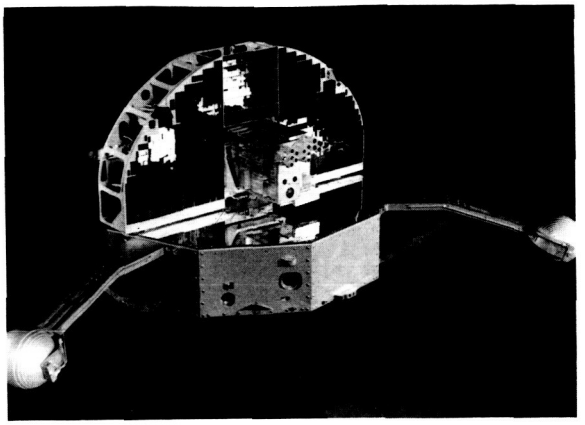
Following the planned trajectory, the payload performance was excellent. The environmental measurements were successful in providing good information on vehicle performance. However, the scientific experiments were a qualified success. The CW propagation experiment was handicapped by the disturbance created in the ionosphere by the rocket discharge, and this prevented calibration of the RF probe. The RF probe, while limited thereby in its usefulness, yielded basic information concerning the theory of operation of the probe. The high-frequency CW signal at 73.6 Mc functioned all through the flight and furnished data for the electron density profile, but with a lower accuracy than that expected if all equipment had functioned fully. The electron density as measured above the ionosphere was lower than that expected on the basis of a knowledge of the underside of the ionosphere. Thus, although the low values obtained by the probe cannot be accepted as highly accurate, they are important. The fact that the gases from the rocket could disturb transmission in the ionosphere to such an extent is, in itself, an important finding.

SATELLITE AND SOUNDING ROCKET PROGRAM IN 1962

Satellite Launches

Tiros IV (1962β1)

This satellite was launched on February 8, 1962, into an orbit with a 48.29 degree inclination, an apogee of 525 miles, and a perigee of 471 miles. One of the TV cameras was a standard Tiros wide-angle type; the second carried a Tegea Knoptik lens not previously used on Tiros. In the scanning radiometer, the 7 to 30μ sensor has been dropped to provide a chan-



Orbiting Solar Observatory, launched March 7, 1962.

nel for picture-timing data. Beacon frequencies have been transferred from the 108-Mc to the 136-Mc band. Otherwise, the satellite was basically the same as Tiros III. Vidicon picture transmission ceased on June 11, 1962, after some 30,000 pictures were transmitted.

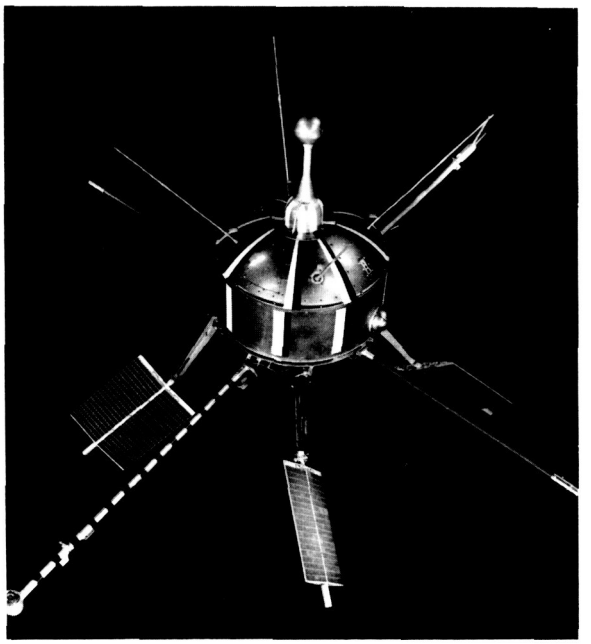
OSO I (1962ζ1)

The Orbiting Solar Observatory satellite, designed for the study of radiations from the sun with instrumentation located above the earth's atmosphere, was launched on March 7, 1962. OSO I weighed about 440 pounds. It reached an orbit with an apogee of 369 miles and a perigee of 343.5 miles, an inclination of 32.8 degrees, and a period of 96.15 minutes. The measurements included ultraviolet radiation studies using narrow-band detectors, gamma-ray experiments to study solar emission in the 0.1 to 500 Mev region, neutron flux measurements from the earth and the sun, and studies of the time variation of solar ultraviolet, x-ray, and gamma-ray emissions. An instrument obtained spectrum and spatial variations in the 1A and 10A radiation region as the instrument's look-angle scanned across the inner corona and the solar disk. Gamma rays in the 0.1 to 5 Mev region were detected by a combination of scintillation counters. An electronic pulse height analysis of the counter pulses yielded the energy spectrum of the rays. To measure gamma rays in the 100 to 500 Mev region, a Cerenkov detector viewed from four directions by multiplier tubes in conjunction with an anticoincidence scintillator was used. The neutron experiment, using BF_3 counters, monitored the neutron flux from the earth and the sun. One objective of this experiment was to determine whether the lower radiation belt arises from the decay of neutrons emitted from the earth.

The satellite consisted of a spinning portion for gyroscopically stabilizing the payload in space and a servo-driven instrumentation section providing azimuth and partial elevation control. This instrumentation section was oriented within 1 minute of arc. It housed about 173 pounds of instrumentation requiring a stabilized view of the sun for operation. Additional instrumentation was carried in the spinning wheel portion of the satellite. Power for the servo-systems and the instruments was furnished by solar cells and rechargeable chemical storage cells. On May 22, 1962, 77 days after launch, OSO completed its useful life. It had made 1138 orbits and observed more than 75 sun flares and subflares.

Ariel I (1962ο1)

On April 26, 1962, at approximately 1300 EST, the first international satellite was launched as a joint United Kingdom–United States project. The satellite was designated as Ariel I, the International Ionosphere Satellite.



Ariel I, launched April 26, 1962.

Ariel I was designed to contribute to man's knowledge of the ionosphere and its complex relation to the sun.

This project developed from proposals made in 1959 to NASA by the British National Committee on Space Research. These proposals were in response to a United States offer to the Committee on Space Research (COSPAR) of the International Council of Scientific Unions to launch scientific experiments or complete satellites prepared by scientists of other nations. The content of the program and the division of responsibility between NASA and the British Committee were agreed during discussions that took place in late 1959 and early 1960. Subsequently, the NASA Administrator assigned project responsibility for the United States to the Goddard Space Flight Center.

This assignment included the design, fabrication, integration, and testing of the spacecraft structure, power supply telemetry, command receiver, thermal control, and data storage. GSFC supplied the vehicle, was responsible for launch, performs data acquisition via the worldwide Minitrack network, and provides data processing. The United Kingdom (U.K.) had the responsibility for the design, fabrication, and testing of all flight sensors and their associated electronics up to the telemetry encoder input. The U.K. also is responsible for data analysis and interpretation.

A list of the experiments and electronic subsystems is as follows.

Experiments

Electron Temperature and Density—University College London

This experiment, based on Druyvesteyn's modification of the Langmuir probe, will determine the value of the electron density and temperature near the satellite.

Ion Mass Composition and Temperature—University College London

This experiment is, basically, the same as the electron temperature experiment. However, the method of measuring the temperature is different.

Solar Lyman-Alpha Emission Measurement—University College London

Two parts of the solar spectrum were selected for measurement: the Lyman-alpha line of hydrogen, and the rather hard x-ray spectrum. The function of the two solar radiation measurements is to enable simultaneous and nearly continuous observations of the state of the ionosphere and of the solar atmosphere.

X-Ray Emission—University College London

This experiment provides an indication of solar conditions.

Solar Aspect Measurement—University College London

The solar aspect subsystem provides the latitude and longitude of the sun in the satellite coordinate system. Also, the subsystem provides the satellite spin rate.

Cosmic Ray Analyzer—Imperial College London

The purpose of this experiment is to make accurate measurements of the primary cosmic ray energy spectrum and the effects of interplanetary magnetic field modulation of this spectrum.

Ionosphere Electron Density Measurement—University of Birmingham

The measurement of electron density is performed by this experiment, and by the Langmuir probes of the University College London. However, the two methods of measurement are quite different and therefore complement one another.

Electronic Subsystems

Telemetry—Goddard Space Flight Center
Data Encoders—Goddard Space Flight Center
Tape Recorder—Goddard Space Flight Center
Power System—Goddard Space Flight Center
Spacecraft Parameters (Housekeeping) System—Goddard Space Flight Center

Spacecraft and orbital characteristics are detailed in the following list.

Scientific Instrumentation

Electron temperature and density sensors (2)
Ion mass sphere (1)
Solar radiation detectors, Lyman-alpha at 1216A (3)
Solar aspect meter (1)
Electron density sensors (1)
X-ray counters (1)

Spacecraft Characteristics

Size, basic structure—23 inches O.D. by 22 inches high
Weight—136 pounds
Spin rate—36 to 12 rpm throughout life
Lifetime—1 year
Power—p-on-n solar cells and nickel-cadmium batteries
Data Storage—100-minute tape recorder
Antenna—modified crossed dipole
Tracking and data frequency—136.408 Mc nominal

Orbit Parameters

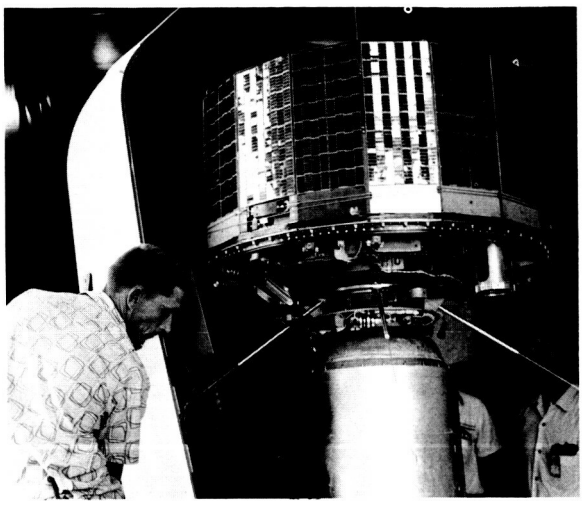
Perigee—242.1 miles
Apogee—754.2 miles
Inclination—53.86 degrees
Period—100.9 minutes
Eccentricity—0.057

Tiros V (1962A-α1)

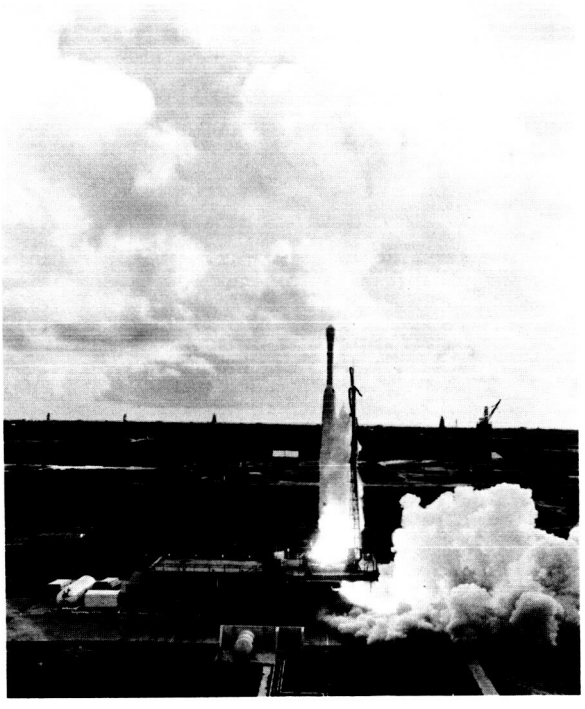
Tiros V was launched on a Delta vehicle from the Atlantic Missile Range (AMR) on June 19, 1962. Weighing 285 pounds, it contained two TV cameras, one having a 104-degree lens and the other a 76-degree lens. The wide-angle coverage averaged about 600,000 square miles—the medium angle lens covering 232,000 square miles.

Its infrared radiation sensors were inoperative at launch; the medium-angle lens camera functioned until July 6, 1962, when a random failure in the electrical system caused it to cease operations.

During the first three months of operation Tiros V produced over 20,000 usable photos covering the first half of the 1962 hurricane season. Tape recorders stored TV pictures taken over areas distant from the two primary command and data acquisitions stations at Wallops



Tiros V is mated to second stage of launch vehicle.



Tiros V liftoff from Cape Canaveral, June 19, 1962.

Island, Va., and the Pacific Missile Range (PMR), San Nicolas, Calif.

The primary objective of the Tiros project was the development of a system capable of viewing the earth's cloud cover, surface, and atmosphere by means of TV cameras and radiation sensors. Ground stations acquired the collected data from the satellite; this information

was subsequently processed for meteorological purposes.

Orbital elements—Perigee, 367 miles; apogee, 604 miles; and period, 100.5 minutes.

Review of Partial Accomplishments of Tiros Program—

Tiros I:

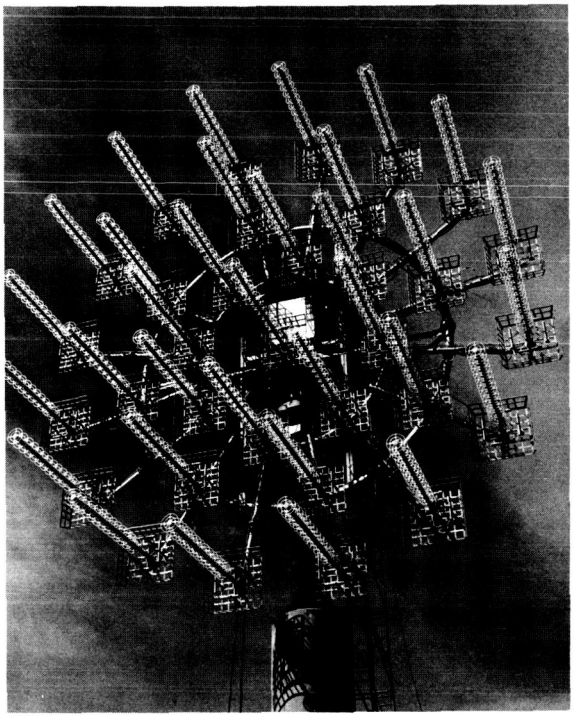
1. Number of usable frames received—19,389
2. Facsimile nephanalyses received—333
   (a) Exact figures on number of charts transmitted are not available
3. A few descriptions partially in plain language and partially in coded form were sent over the teletype. There is no record of which passes or of the total number of passes described

Tiros II:

1. Number of usable frames received—25,574
2. Facsimile nephanalyses received—455 (November 23, 1960–August 18, 1961)
   (a) Number retransmitted—305
3. Coded nephanalyses transmitted (approx.)—295

Tiros III (July 12 through October 30, 1961):

1. Number of usable frames received—24,000
2. Facsimile nephanalyses received—755
   (a) Number retransmitted—744
3. Coded nephanalyses via teletype (approx.) —665
4. Satellite storm advisories issued—70
   (Includes messages to Mexico, Guam, Japan, Philippines, Formosa, Hong Kong, Meuritius, Miami, San Juan, New Orleans, San Francisco, Honolulu)
5. Suggested adjustments to NMC analyses—76
6. Hurricanes observed: Anna, Betsy, Carla, Debbie, Esther, Frances
7. Typhoons observed: Kathy, Lorna, Marie, Nancy, Pamela, Ruby, Sally, Tilda
8. Projects supported:
   (a) Project Mercury
   (b) Ranger
   (c) Discoverer
   (d) Firing of Long Tom Meteorological Rockets in Australia
   (e) Antarctic resupply mission
   (f) U.S. Navy operations in South American waters



A Wallops antenna that receives video signals from Tiros V.

Tiros IV (February 8 through June 12, 1962):

1. Number of usable frames received—23,370
2. Facsimile nephanalyses:
   Total number received—836
   Wallops Is.—621
   PMR—215
   Total number retransmitted—795
3. Coded nephanalyses via teletype:
   Total—694
   Wallops Is.—621
   PMR—133
   Programming & Processing Section—333
4. Satellite storm advisories issued—102
   (Includes messages to Japan; Malagney Republic; Meuritius; Republic of South Africa; Seattle; San Francisco; Los Angeles; Honolulu; USAF Air Weather Service detachments in Hawaii, Guam, and Japan; New Zealand; Australia; Chile; Miami; San Juan; and Argentina)
5. Number of adjustments suggested and made in analyses of the National Meteorological Center. Includes following types:
   (a) Frontal positions adjusted — 39

(b) Frontal vanes added or position adjusted — 8
(c) Surface pressure centers adjusted or added — 25
(d) 500 mb centers adjusted — 5
(e) 50 mb troughs adjusted — 2

79

6. Tiros IV was programmed to support the following projects:

(a) TIRIC
(b) Joint Task Force 8
(c) Ranger
(d) Univ. of Wisconsin research on ice-covered lakes
(e) Discoverer launch and horizon sensor check
(f) California water survey of U.S. Weather Bureau—pictures of snow on Sierras
(g) USAF—AWS detachment, Adana, Turkey operational purposes
(h) USAF—AWS detachment 1, 1st WW, Japan—Japan—operational purposes
(i) USAF—AWS 3rd Weather Wing—coverage of Asia
(j) Project Bright Cloud—AFORC—ORD research program to study coincident aircraft photography, ground radar photography, and Tiros pictures.
(k) Project Mercury
(l) Antarctic Resupply Missions—nephanalysis charts covering southern Indian Ocean areas were transmitted by U.S. Navy directly to McMurdo Sound, Antarctica. Daily composite nephanalysis charts were mailed daily to the International Antarctic Analysis Center, Melbourne, Australia.
(m) Australian rocket firing—Long Tom Meteorological Rockets were fired near Woomera on May 30 in conjunction with a Tiros pass.
(n) University of Miami research project investigating radarscope photography.

Tiros V:

Tropical Storms: Ava (Pacific off West Coast)

Typhoons: Opal, Ruth, Sarah, Thelma

Tiros V photographed the vortex of a storm off the northeast coast of Newfoundland, June 19, 1962, 1:48 p.m. EDT.

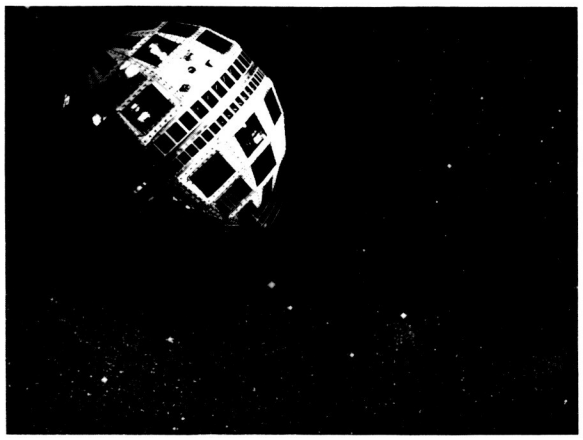
Telstar I (1962A–c1)

The success of Project Echo, a *passive* communications satellite, led to the initiation of an *active* satellite development and construction program by the American Telephone and Telegraph Company (AT&T).

It was implemented under a cooperative agreement between AT&T and NASA. Under two terms of this agreement, Goddard Space Flight Center was made responsible for: procuring, testing, and launching a Delta vehicle to orbit the Telstar spacecraft; verifying the qualifications of the spacecraft; and integrating it with the launch vehicle. In addition, GSFC provided acquisition data and telemetry tapes for a period of 2 months after launch. The AT&T bore all costs of its own activity under the cooperative project and reimbursed GSFC for costs incurred by the Government in

supporting the Telstar project. Telstar was launched July 10, 1962.

Many communications experiments with this satellite have been highly successful and have received worldwide acclaim.



Telstar I, launched July 10, 1962.

As a result of the successful performances of this experimental satellite, considerable public and official interest was aroused. This led to legislation (Public Law 87–624, 87th Congress, Aug. 31, 1962), to provide for the establishment, ownership, operation, and regulation of a commercial communications satellite system.*

Tiros VI (1962A–ψ1)

Launched September 18, 1962, Tiros VI had as objectives the study of cloud-cover and earth heat balance, and the measurement of radiation in selected spectral regions as part of a program to develop meteorological satellite systems. Instrumentation included two TV camera systems (78-degree and 104-degree lens), clocks and tape recorders for remote operation, infrared and attitude sensors, and magnetic altitude coil. The medium-angle camera failed on December 1, 1962, after taking 1074 pictures.

Alouette (1962B–α1)

Alouette, a swept frequency topside sounder, was a project of the Canadian Defence Research Board. This project was a part of NASA's Topside Sounder Program. It was the first NASA satellite to be launched from the Pacific Missile Range. It was the first spacecraft designed and built by any other country than the U.S. and U.S.S.R. Among its objectives were: measurement of the electron density distribution in the ionosphere between 180 and 620 miles, study of variations of electron density distribution under varying conditions, determination of the electron densities in the vicinity of the satellite, and observations of related physical phenomena. Launch was made September 29, 1962.

Explorer XIV (1962B–γ1)

The Energetic Particles Satellite was launched on October 2, 1962, and contained a cosmic-ray experiment, an ion detector experiment, a solar cell experiment, probe analysis, a trapped radiation experiment, and a magnetometer experiment. Its objectives were to describe the trapped corpuscular radiation, solar particles, cosmic radiation, and the solar winds and to correlate the particle phenomena with the magnetic field observations.

Explorer XV (1962B–λ1)

This satellite was launched October 27, 1962, for the purpose of studying the new artificial radiation belt created by nuclear explosions. It acclaimed experiments in electron energy distribution, an omnidirectional detector, an angular distributor, directional detector, ion-electron detector, a magnetic field experiment, and a solar cell gauge. Good data were received from this satellite.

Relay (1962B–υ1)

Relay was launched December 13, 1962. It contained an active communications repeater to receive and retransmit communications between the U.S. and Europe, and an experiment to assess radiation damage to solar cells. Its objectives were to investigate wideband communications between ground stations by means of low-altitude orbiting spacecraft. Communications signal to be evaluated was an assortment of television signals, multi-channel telephony, and other communications. The wideband stations used were: Rumford, Me.; Pleumeur-Bodon, France; Goonhilly, England; Weilhelm, W. Germany. Narrowband stations were: Nutley, N.J., and Rio de Janeiro, Brazil.

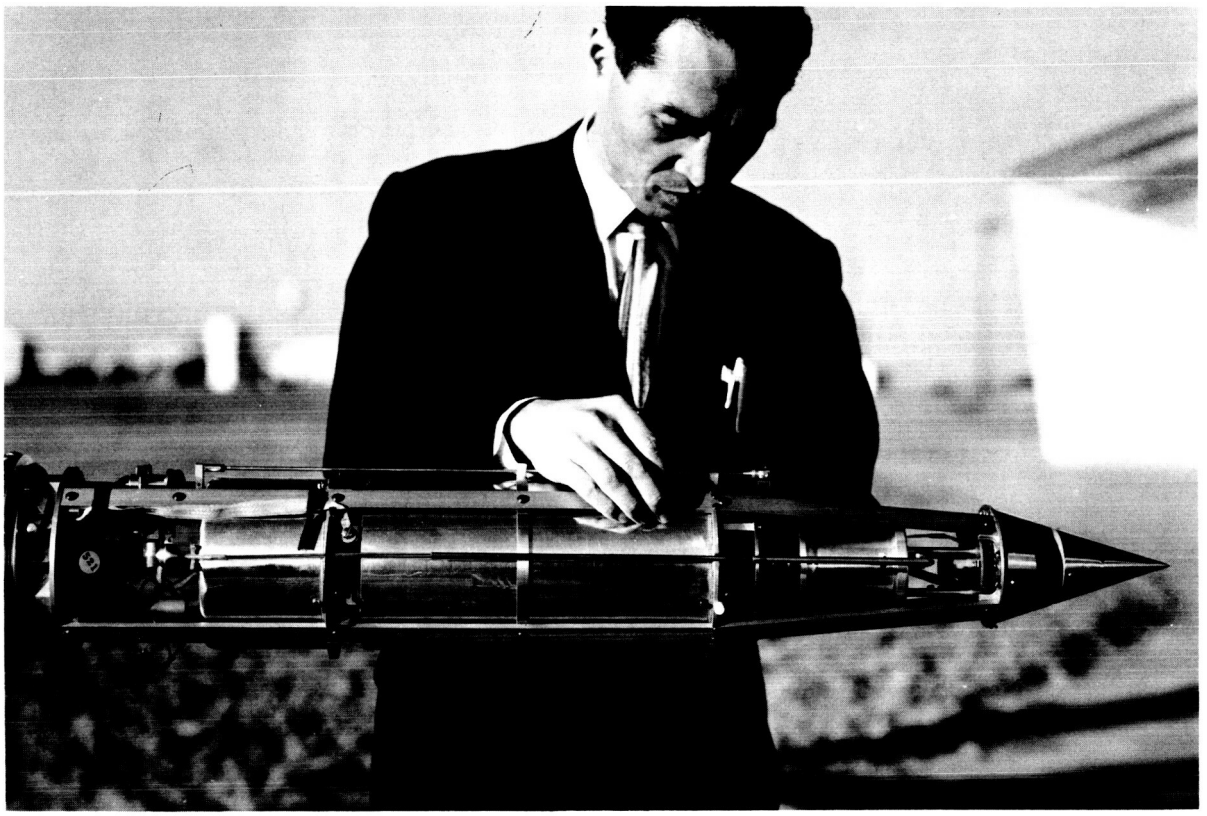
*See Appendix D, exhibits 15 and 16.

Early experience with this satellite further demonstrated the feasibility of such a system of communications.

Sounding Rockets, 1962

Goddard Space Flight Center successfully launched 70 sounding rockets carrying scientific instrumentation during the period from January 1, 1962, to December 31, 1962. Degree of success breakdown is as follows:

47—Successful
5—Partially sucessful
18—Unsuccessful



A closeup of the sounding rocket used in the first joint flight effort by the United States and Japan.

1962 Sounding Rocket Flights

Vehicle*	Firing			Project Scientist	Experiment	Result‡
	Date	Site†	Performance ‡			
Aerobee 150A GT	Jan. 13	WI	S	Russell	Attitude control	S
Aerobee 150A GG	Feb. 7	WI	X	Stecher	Stellar spectra	X
Argo D4 AI	7	WI	S	Jackson	Ionosphere	X
Aerobee 150A NP	17	WI	S	Lewis Research Center (LRC)—Dillon	Zero G	S
Nike-Cajun UA	20	WI	S	U. of Mich.—Dubin	Atm. structure	X
Nike-Cajun CA	March 1	WI	S	GCA—Smith	Sodium vapor	S
GT	1	WI	X	Donn	Water launch	S
GA	2	WI	S	Smith	Grenade	S
GT	2	WI	S	Donn	Water launch	S
CA	2	WI	S	GCA—Smith	Sodium vapor	S
GA	2	WI	S	Smith	Grenade	S
Aerobee 150A GA	19	WI	X	U. of Mich—Spencer	Atm. structure	X
Nike-Cajun CA	23	WI	S	GCA—Smith	Sodium	S
GA	23	WI	S	Smith	Grenade	S
CA	27	WI	S	GCA—Smith	Sodium	S
GA	28	WI	S	Smith	Grenade	S
Nike-Cajun NA	Apr. 5	WI	S	LRC—Potter	Ozone	S
GA	17	WI	S	Smith	Grenade	S
Nike-Asp CA	17	WI	S	GCA—Smith	Sodium	S
Nike-Cajun GI	26	WI	S	Serbu	Electron temp.	S
Iris GA	May 3	WI	P	Taylor	Atm. Structure	S
Argo D4 GI	3	WI	S	Serbu	ELF electron trap	P
Aerobee 150 NP	8	WSMR	S	Jet Propulsion Lab. (JPL)—Brown.	Radar	X
Nike-Cajun GI	16	WI	S	Serbu	Electron temp.	S
GI	17	WI	S	Serbu	Electron temp.	S
UA	18	WI	S	Schaeffer	Massenfilter	S
Aerobee 150A GI	25	WI	S	Pressly	Sea recovery	S
Nike-Apache UA	June 6	WI	S	U. of Mich.—Spencer	Atm. structure	S

See footnotes at end of table.

1962 Sounding Rocket Flights—Continued

Vehicle*	Firing			Project Scientist	Experiment	Result‡
	Date	Site†	Performance ‡			
Nike-Cajun						
GA	June 7	WI	S	Smith	Grenade	S
Nike-Asp						
CA	7	WI	S	GCA—Smith	Sodium	S
CA	7	WI	X	GCA—Smith	Sodium	X
Nike-Cajun						
GA	8	WI	S	Smith	Grenade	S
Nike-Apache						
GI	15	WI	S	Kane	Ionosphere	S
Aerobee 150A						
NP	20	WI	S	LRC—Flagge	Zero G	P
US	29	WI	S	Johns Hopkins Univ. (JHU)—Depew	Airglow	S
US	29	WI	S	JHU—Depew	Airglow	S
Aerobee 150						
NP	July 10	WSMR	S	JPL	Radar	X
Aerobee 150A						
US	24	WI	S	U. of Colorado	Sunfollower	P
Aerobee 150A						
GT	Aug. 8	WI	P	Russell	Attitude control	P
Nike-Apache						
CA	23	WI	P	Lockheed Aircraft Corp.	Atm. structure	X
Aerobee 100						
NA	Sept. 6	WSMR	S	JPL	UV airglow	S
Argo D8						
UR	22	WI	S	U. of Mich.	Radio astronomy	S
Aerobee 150A						
GG	22	WI	S	Stecher	Stellar photo	X
CG	30	WI	S	Lockheed Aircraft Corp.	Night sky mapping	S
Nike-Apache						
GI	Oct. 16	WI	S	Bauer	Ionosphere	S
Aerobee 150A						
UG	30	WI	S	U. of Wisc.	Stellar studies	S
Nike-Cajun						
CI	Nov. 7	WI	S	GCA	Ionosphere	S
Nike-Asp						
CA	7	WI	S	GCA	Sodium	S
Aerobee 150A						
II	16	WI	X	Australia	Ionosphere	X
Nike-Cajun						
GA	16	FC	X	W. Smith	Grenade	X
Aerobee 150A						
NP	18	WI	S	LRC	Zero G	S
Aerobee 100						
NA	20	WSMR	X	JPL	UV airglow	X
Aerobee 300						
GA	20	WI	S	Brace	Thermosph. probe	S

See footnotes at end of table.

1962 Sounding Rocket Flights—Continued

Vehicle*	Firing			Project Scientist	Experiment	Result‡
	Date	Site†	Performance‡			
Aerobee 150A US	Nov. 27	WSMR	S	Harvard Univ.	Solar	X
Nike-Cajun CI	30	WI	S	GCA	Ionosphere	S
Nike-Apache CA	30	WI	S	GCA	Sodium	S
Nike-Apache GI	Dec. 1	WI	S	Bauer	Ionosphere	S
UA	1	WI	S	U. of Mich.	Atm. structure	S
Nike-Cajun GA	1	WI	S	W. Smith	Grenade	S
GA	1	FC	S	W. Smith	Grenade	X
Nike-Apache AA	1	Eglin	S	AF Cambridge Research Lab. (AFCRL)	Sodium	X
Nike-Cajun GA	4	WI	X	W. Smith	Grenade	X
GA	4	FC	S	W. Smith	Grenade	S
Nike-Apache AA	4	Eglin	S	AFCRL	Sodium	S
Nike-Cajun CI	5	WI	S	GCA	Ionosphere	S
Nike-Apache CA	5	WI	S	GCA	Sodium	P
Nike-Cajun GA	6	WI	S	W. Smith	Grenade	S
GA	6	FC	S	W. Smith	Grenade	S
Aerobee II	11	WI	X	Australia	Ionosphere	X
UA	13	WI	X	JHU	Airglow	X

*Note: The letters which follow each vehicle identification identify (1) the instrumenting agency, and (2) the experiment, according to the following list:

(1) *Agency*
A—Other government agency
C—Industrial corporation
D—DOD
G—GSFC
I—International
N—Other NASA centers
U—College or university

(2) *Experiment*
A—Aeronomy
B—Biological
E—Energetic particles and fields
G—Galactic astronomy
I—Ionospheric physics
P—Special projects
R—Radio astronomy
S—Solar physics
T—Test and support

†WI—Wallops Island, Va.
WSMR—White Sands Missile Range
FC—Fort Churchill, Canada
Eglin—Eglin Air Force Base

‡S—Successful
X—Unsuccessful
P—Partial success

Grenades

The launch of a series of rocket grenades resulted in obtaining much useful data in measuring wind and temperature, and in deriving density and pressure from 90 to 100 km.

Zero G Experiments

These experiments with sounding rockets were instrumented to determine heat-transfer coefficients under conditions of a spherical low radiant heat input and zero gravity. The instrumentation performance produced generally satisfactory results.

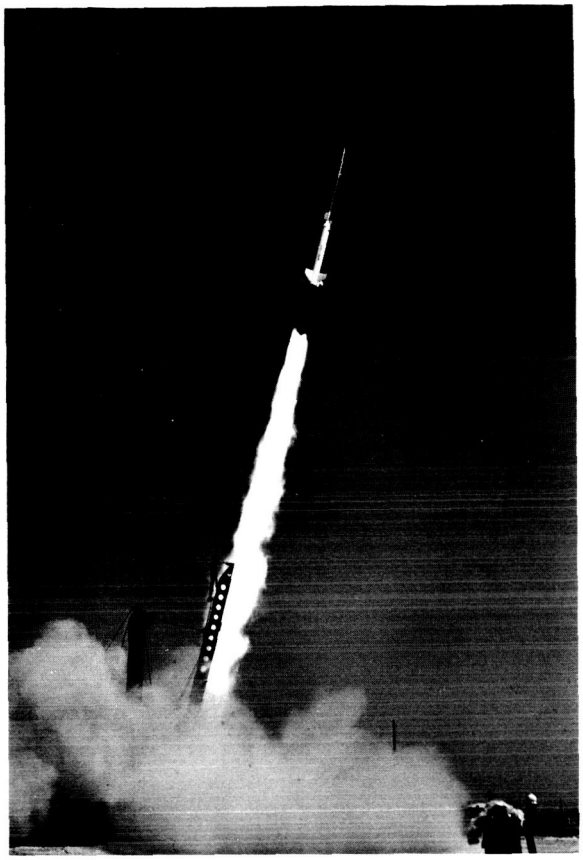
Ionosphere

Several experiments were conducted to measure electron density and electron temperature. Profiles of electron density under various conditions were obtained.

Sodium Vapor

The objectives of these experiments were to measure upper atmospheric winds and diffusion

rates. Considerable data of value were obtained through optical observation of performance and radiosonde technique.



On April 26, 1962, the Japanese electron temperature experiment was launched from Wallops Island by a Nike–Cajun rocket.

Electron Trap

Experiments in this field were for the purpose of studying the intensity and distribution of radio noise from the galaxy at extremely low frequency and for measuring the electron temperature and the charge density as a function of altitude in the lower ionosphere. The Langmuir probe experiment conducted by GSFC and the RF resonance probe experiment, conducted by the Radio Research Laboratory, Tokyo, Japan, constituted a joint effect to measure electron temperature simultaneously by independent techniques.

Other Rocket Grenade Experiments

Experiments with sounding rockets by GSFC during 1962 were:

An experiment to test the water recovery system. This system performed as expected, and the unit was considered suitable for satellite use.

Experiments to determine sky glow were for the purpose of observing, in a previously unobserved region of the spectrum, the night sky emissions and of measuring their intensity as a function of altitude. Instrumentation performance was excellent.

A sounding rocket was launched for the purpose of measuring the energy distribution of early type stars. Observations were made of several stars during this flight, but detailed data reduction will require considerable time.

A coordinated series of sounding rocket grenade experiments was made to obtain data on pressure, density, and temperature up to 120 km; to obtain ion composition data through the use of a new ceramic RF ion spectrometer; and, by using the pitot static technique, to measure pressure density and temperatures.

An experiment to help map night sky sources which emit photons in the 6A to 0.6A wavelength interval produced quite satisfactory results.

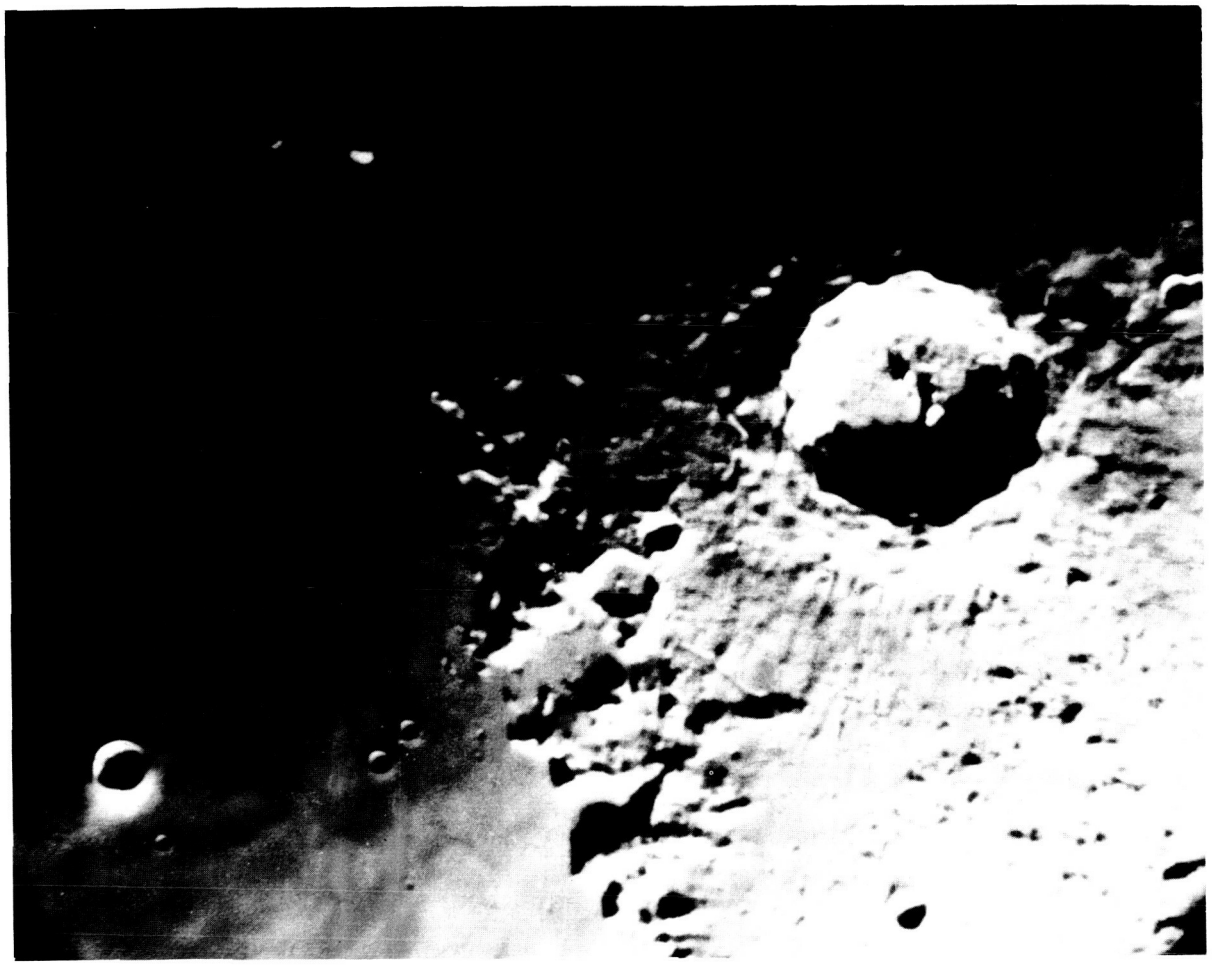
Other sounding rockets measured the intensity of RF energy at medium frequencies originating previously in our galaxy, measured the composition and density of the atmosphere from 95 km to peak altitude through the use of the Paul Massenfilter, measured ultraviolet day airglow spectrum in the wavelength between 1650A and 3000A, simultaneously measured electron and neutral particle temperatures in the altitude region of 120 to 360 km, studied the wavelength profile as a function of altitude, and tested the rocket attitude control system of the 150A Aerobee rocket.

Chapter 8

THE FUTURE

In concluding a preliminary historical account of the early years of the Goddard Space Flight Center, detailed analysis and evaluation must await the processes of much scientific collation and the passage of time. Yet the people, plant, and programs of the Goddard Center, integrally a part of the fast-paced U.S. space program, are dedicated to the acquisition of newly accessible scientific knowledge of the vast space environment—of inevitable significance to the understanding of mankind on earth. This central idea of the scientific exploration of space was expressed by the Director of Goddard Space Flight Center, Dr. Harry J. Goett, as follows:

> "The characteristic of space science is such that it spreads across many disciplines, and a very broad segment



Splash crater on the moon.

of the scientific fraternity is helping unravel the meaning of the new scientific data being brought back from outer space. You must recognize the efforts of the orbital mechanicians, physicists with various areas of specialization, astronomers, geologists, and geodists in the analysis of the results . . . Each of these disciplines is finding that it has a new frontier. New areas of research are being created by the data which rockets and satellites provide. We surely have just started to realize their potentials.

"The job of putting together the cosmic jigsaw of space from the bits and pieces of data obtained from our satellites is one that engages the effort of many people throughout the scientific community; and this jigsaw puzzle goes together so gradually that there are no singular events which merit a headline. There are Nobel prizes in the making, but it is going to be difficult to determine who should get the medal."*

Goddard's hopes for the future may best be summed up by quoting from an address by the Hon. James E. Webb, Administrator, National Aeronautics and Space Administration:

"Technological advances through our space effort will, I am convinced, bring us total benefits exceeding those of any other scientific and technical undertaking in history, dwarfing every previous opening of new territories and new knowledge."†

*Scientific Exploration of Space," by Dr. Harry J. Goett, as presented before the Aviation and Space Writers Association, at San Francisco, California, on May 25, 1962. (See Appendix C.)

†Address by James E. Webb, Administrator, National Aeronautics and Space Administration, at the Webb School Alumni Association Testimonial Dinner, Los Angeles, California, April 26, 1962.

Appendixes

Man, being the servant and interpreter of Nature, can do and understand so much and so much only as he has observed in fact or in thought of the course of nature: beyond this he neither knows anything nor can do anything.

—*Francis Bacon*

Goddard's top management staff. From left to right: Dr. M. J. Vacarro, Mr. J. T. Mengel, Dr. E. W. Wasielewisk, Dr. H. J. Goett, Dr. J. W. Townsend, and Mr. L. Winkler.

Appendix A

GODDARD SPACE FLIGHT CENTER SATELLITE AND SPACE PROBE PROJECTS AS OF DECEMBER 1962

Goddard Space Flight Center Satellites and

Designation	Date		Launch Vehicle and Site	Objectives	Instrumentation	Period Minutes
	Launch	Silent				
Explorer VI 1959 Delta I (S-2)	Aug. 7, 1959	Oct. 6, 1959	Thor-Able AMR	Measure three specific radiation levels of earth's radiation belts; test scan for earth's cloud cover; map earth's magnetic field; measure micrometeorites; study behavior of radiowaves.	Equipment to measure radiation levels; TV-type scanner; micrometeorite detector; two types of magnetometer; and devices for space communication experiments.	12½ hours
Vanguard III 1959 Eta	Sept. 18, 1959	Dec. 12, 1959	Vanguard AMR	Measure the earth's magnetic field, x-radiation from the sun, and several aspects of the space environment through which the satellite travels.	Proton precisional magnetometer, ionization chambers for solar x rays, micrometeor detectors, and thermistors.	130
Explorer VII (S-1a)	Oct. 13, 1959	Aug. 24, 1961	Juno II AMR	Variety of experiments, including solar ultraviolet; x-ray; cosmic-ray, earth radiation and micrometeor experiments.	Sensors for measurements of Earth-Sun heat balance; Lyman-alpha and x-ray solar radiation detectors; micrometeor detectors, Geiger-Mueller tubes for cosmic-ray count; ionization chamber for heavy cosmic rays.	101.33

Space Probe Projects as of December 1962

Orbital Elements		Project Manager and Project Scientist	Experiment	Experimenter	Affiliation	Remarks
Perigee (Statute miles)	Apogee (Statute miles)					
156	26,357	Dr. John C. Lindsay	Triple coincidence telescopes	J. A. Simpson C. Y. Fan P. Meyer	U. of Chicago	Orbit achieved. All experiments performed. First complete televised cloud-cover picture obtained. Detected large ring of electrical current circling Earth; complete map of Van Allen radiation belt obtained.
		Dr. John C. Lindsay	Scintillation counter	T. A. Farley A. Rosen C. P. Sonnett	Space Technology Laboratories	
			Ionization chamber Geiger counter	J. Winckler	U. of Minn.	Weight: 142 lb
			Spin-coil magnetometer	E. J. Smith D. L. Judge	STL	Power: Solar
			Fluxgate magnetometer	P. J. Coleman	STL	
			Aspect sensor		STL	
			Image-scanning television system		STL	
			Micrometeorite detector		Cambridge Research/STL	
319	2329		Proton magnetometer	Dr. J. P. Heppner	GSFC	Orbit achieved. Provided comprehensive survey of earth magnetic field over area covered; surveyed location of lower edge of Van Allen radiation belts. Accurate count of micrometeorite impacts.
			Ionization chambers	H. Friedman	NRL	
			Environmental measurements	H. E. LaGow	GSFC	Weight: 100 lb including attached 3rd stage
						Power: Battery
342	680	H. LaGow	Thermal radiation balance	V. Suomi	U. of Wisc.	Orbit achieved. Provided significant geophysical information on radiation and magnetic storms; demonstrated method of controlling internal temperatures; first micrometeorite penetration of a sensor in flight.
			Solar x ray and Lyman-alpha	H. Friedman R. W. Kreplin T. Chubb	NRL	
			Heavy cosmic radiation	G. Groetzinger P. Schwed M. Pomerantz	Martin Co. Bartol Research	Weight: 91.5 lb
			Radiation and solar-proton observation	J. Van Allen G. Ludwig H. Whelpley	St. U. of Iowa	Power: Solar
			Ground-based ionospheric observations	G. Swenson Dr. C. Little G. Reid O. Villard, Jr. W. Ross W. Dyke	U. of Illinois Nat. Bu. of Stand. U. of Alaska Stanford Univ. Penn State Univ. Linfield Res. Inst.	
			Micrometeorite penetration experiment	H. LaGow	GSFC	

Goddard Space Flight Center Satellites and Space

Designation	Date		Launch Vehicle and Site	Objectives	Instrumentation	Period Minutes
	Launch	Silent				
Pioneer V 1960 Alpha	Mar. 11, 1960	June 26, 1960	Thor-Able AMR	Investigate interplanetary space between orbits of Earth and Venus, test extreme long range communications, study methods for measuring astronomical distances.	High-intensity radiation counter, ionization chamber, Geiger-Mueller tube to measure plasmas, cosmic radiation, and charged solar particles. Magnetometer and micrometeorite temperature measurements.	311.6 days
Tiros I 1960 Beta (A-1)	April 1, 1960	June 12, 1960	Thor-Able AMR	Test experimental television techniques leading to eventual worldwide meteorological information system.	One wide and one narrow angle camera, each with tape recorder for remote operation. Picture data can be stored on tape or transmitted directly to ground stations.	99.1
Echo I 1960 Iota	Aug. 12, 1960	Still in orbit	Thor-Delta AMR	Place 100-foot inflatable sphere into orbit.	Two Minitrack tracking beacons on sphere.	118.3
Explorer VIII 1960 Xi (S-30)	Nov. 3, 1960	Dec. 28, 1960	Juno II AMR	Investigate the ionosphere by direct measurement of positive ion and electron composition; collect data on the frequency momentum and energy of micrometeorites impacts; establish the attitude of the base of the exosphere.	RF impedance probe using a 20-foot dipole sensor; single grid ion trap; four multiple-grid ion traps; Langmuir probe experiment; rotating shutter electric field meter; micro plier; micrometeorite microphone; thermistors for reading internal and surface temperatures of the space craft; and despin mechanisms to reduce spin from 450 to 30 rpm.	112.7
Tiros II 1960 Pi I (A-2)	Nov. 23, 1960	Feb. 7, 1961	Delta AMR	Test experimental television techniques and infrared equipment leading to eventual worldwide meteorological information system.	Includes one wide and one narrow angle camera, each with tape recorder for remote operation; infrared sensors to map radiation in various spectral bands; attitude sensors; experimental magnetic orientation control.	98.2

Probe Projects as of December 1962—Continued

Orbital Elements		Project Manager and Project Scientist	Experiment	Experimenter	Affiliation	Remarks
Perigee (Statute miles)	Apogee (Statute miles)					
Perihelion 74.9 million from sun.	Aphelion 92.3 million from sun.	Dr. John C. Lindsay	Triple coincidence proportional counter	J. Simpson	U. of Chicago	Highly successful exploration of interplanetary space between orbits of Earth and Venus; established communication record of 22.5 million miles on 6/26/60; made measurements of solor flare effects, particle energies and distribution, and magnetic field phenomena in interplanetary space.
		Dr. John C. Lindsay	Cosmic-ray telescope Search-coil magnetometer and photoelectric cell aspect indicator	D. Judge	STL	
			Ionization chamber and G–M tube	J. Winckler	U. of Minn.	Weight: 94.8 lb
			Micrometeorite counter	E. Manring	AFCRC	Power: Solar
428.7	465.9	W. G. Stroud (GSFC) H. Butler (Army)	TV camera systems (2)			Provided 1st global cloud-cover photographs (22,952 total) from near-circular orbit. Weight: 270 lb Power: Solar
945	1049	Robert J. Mackey				Demonstrated use of radio reflector for global communications, numerous successful transmissions. Visible to the naked eye. Weight: 132 lb (including inflation powder). Power: Passive
258	1423	Robert E. Bourdeau	RF impedance	J. Cain	GSFC	Measured the electron density temperature, ion density and composition, and charge on the satellite in the upper ionosphere. The micrometeorite influx rate was measured.
		Robert E. Bourdeau	Ion traps	R. Bourdeau G. Serbu E. Whipple J. Donley	GSFC	
			Langmuir probe	R. Bourdeau G. Serbu E. Whipple J. Donley	GSFC	Weight: 90.14 lb Power: Battery
			Rotating-shutter electric field meter	J. Donley	GSFC	
			Micrometeorite photomultiplier	M. Alexander K. McCracken O. Berg	GSFC	
			Micrometeorite microphone	M. Alexander K. McCracken	GSFC	
406	431	Dr. R. Stampfl	TV camera systems (2)			Orbit achieved. Narrow-angle camera and IR instrumentation sent good data. Transmitted 36,156 pictures. Still operative. Weight: 277 lb Power: Solar
			Widefield radiometer experiment	Dr. W. Nordberg	GSFC	
			Scanning radiometer experiment	Dr. R. A. Hanel	GSFC	

Goddard Space Flight Center Satellites and Space

Designation	Date		Launch Vehicle and Site	Objectives	Instrumentation	Period Minutes
	Launch	Silent				
Explorer IX 1961 Delta I (S-56a)	Feb. 16, 1961	Passive satellite	Scout Wallops Island	Study performance, structural integrity, and environmental conditions of Scout research vehicle and guidance controls system. Inject inflatable sphere into earth orbit to determine density of atmosphere.	Radio beacon on balloon and in fourth stage.	118.3
Explorer X 1961 Kappa (P-14)	Mar. 25, 1961	Mar. 27, 1961	Thor-Delta AMR	Gather definite information on earth and interplanetary magnetic fields and the way these fields affect and are affected by solar plasma.	Includes rubidium-vapor magnetometer, two fluxgate magnetometers, a plasma probe, and an optical aspect sensor.	112 hours
Explorer XI 1961 Nu I (S-15)	Apr. 27, 1961	Dec. 6, 1961	Juno II AMR	Orbit a gamma ray astronomy telescope satellite to detect high energy gamma rays from cosmic sources and map their distribution in the sky.	Gamma ray telescope consisting of a plastic scintillator, crystal layers, and a Cerenkov detector; sun and earth sensors; micrometeorite shields; temperature sensor; damping mechanism.	108.1
Tiros III 1961 Rho I (A-3)	July 12, 1961	Dec. 4, 1961	Thor-Delta AMR	Develop satellite weather observation system; obtain photos of of earth's cloud cover for weather analysis; determine amount of solar energy absorbed, reflected, and emitted by the earth.	Two wide-angle cameras, two tape recorders and electronic clocks, infrared sensors, five transmitters, attitude sensors, magnetic attitude coil.	100.4
Explorer XII 1961 Upsilon I (S-3)	Aug. 15, 1961	Dec. 6, 1961	Thor-Delta AMR	Investigate solar wind, interplanetary magnetic fields, distant portions of earth's magnetic field, energetic particles in interplanetory space and in the Van Allen belts.	Ten particle detection systems for measurement of protons and electrons and three orthogonally mounted fluxgate sensors for correlation with the magnetic fields, optical aspect sensor, and one transmitter. Telemetry is PFM and transmits continuously.	26.45 hours
Explorer XIII 1961 Chi	Aug. 25, 1961	Aug. 27, 1961	Scout Wallops Island	Test performance of the vehicle and guidance; investigate nature and effects on space flight of micrometeoroids.	Micrometeroids impact, detectors, transmitters.	97.5

Probe Projects as of December 1962—Continued

Orbital Elements		Project Manager and Project Scientist	Experiment	Experimenter	Affiliation	Remarks
Perigee (Statute miles)	Apogee (Statute miles)					
395	1605					Vehicle functioned as planned. Balloon and fourth stage achieved orbit. Transmitter on balloon failed to function properly function properly requiring optical tracking of balloon. Weight: 80 lb Power: Passive
100	186,000	Dr. J. P. Heppner Dr. J. P. Heppner	Rubidium-vapor magnetometer and fluxgate magnetometers Plasma probe Spacecraft attitude experiment	Dr. J. P. Heppner T. L. Skillman C. S. Scearce H. Bridge F. Scherb B. Rossi J. Albus	GSFC MIT GSFC	Probe transmitted valuable data continuously for 52 hours as planned. Demonstrated the existence of a geomagnetic cavity in the solar wind and the existence of solar proton streams transporting solar interplanetary magnetic fields past the earth's orbit. Weight: 79 lb Power: Battery
304	1113.2	Dr. J. Kupperian, Jr. Dr. J. Kupperian, Jr.	Gamma-ray telescope	W. Kraushaar G. Clark	MIT	Orbit achieved. Detected first gamma rays from space. Directional flux obtained. Disproved one part of "steady state" evolution theory. Weight: 82 lb Power: Solar
461.02	506.44	R. Rados	Omnidirectional radiometer Widefield radiometer experiment Scanning radiometer experiment TV cameras (2)	V. Suomi Dr. W. Nordberg Dr. R. A. Hanel	U. of Wis. GSFC GSFC	Orbit achieved. Cameras and IR instrumentation transmitted good data. Transmitted 35,033 pictures. First hurricane covering international program. Weight: 285 lb Power: Solar
180	47,800	P. Butler Dr. F. McDonald	Proton analyzer Magnetometer Cosmic ray Ion-electron detector Solar cell	M. Bader L. Cahill B. O'Brien Dr. F. B. McDonald L. Davis G. Longanecker	Ames Research Center U. of New Hampshire St. U. of Iowa GSFC GSFC GSFC	Orbit achieved; all instrumentation operated normally. Ceased transmitting on Dec. 6, 1961, after sending 2568 hours of real-time data. Provided significant geophysical data on radiation and magnetic fields. Weight: 83 lb Power: Solar
74	722	C. T. D'Aiutolo	A cadmium sulfide photoconductor experiment A wire grid experiment	M. W. Alexander L. Secretan	GSFC	Orbit was lower than planned. Reentered August 27, 1961. Weight: 187 lb including 50 lb 4th stage and 12 lb transition section. Power: Solar

Goddard Space Flight Center Satellites and Space

Designation	Date		Launch Vehicle and Site	Objectives	Instrumentation	Period Minutes
	Launch	Silent				
P21 Electron Density Profile Probe (P-21)	Oct. 19, 1961	Oct. 19, 1961	Scout Wallops Island	Measure electron densities and investigate radio propagation at 12.3 and 73.6 Mc under daytime conditions.	Continuous-wave propagation experiment for the ascent portion of the trajectory, and an RF probe technique for the descent.	
Tiros IV 1962 Beta (A-9)	Feb. 8, 1962	June 19, 1962	Delta AMR	Develop principles of weather satellite system; obtain cloud and radiation data for use in meteorology.	Two TV camera systems with clocks and recorders for remote pictures, infrared sensors, heat budget sensors, magnetic orientation control horizon sensor, north indicator.	100.4
Orbiting Solar Observatory OSO-1 1962 Zeta (S-16)	Mar. 7, 1962	Active	Delta AMR	Place satellite in earth orbit to measure solar electromagnetic radiation in the ultra-violet, x-ray and gamma-ray regions; investigate effect of dust particles on surfaces of spacecraft.	Devices to conduct 13 different experiments for study of solar electromagnetic radiations; investigate dust particles in space and thermal radiation characteristics of spacecraft surface materials.	96.15
P21A Electron Density Profile Probe (P-21A)	Mar. 29, 1962	Mar. 29, 1962	Scout Wallops Island	Measure electron density profile, ion density, and type of ions in the atmosphere.	A continuous-wave propagation experiment to determine electron density and associated parameters of ionosphere. A swept frequency probe for direct measurements of electron density and a positive ion experiment to determine ion concentration under night-time conditions.	

Probe Projects as of December 1962—Continued

Orbital Elements		Project Manager and Project Scientist	Experiment	Experimenter	Affiliation	Remarks
Perigee (Statute miles)	Apogee (Statute miles)					
N/A	N/A 4261	John E. Jackson Dr. S. J. Bauer	RF probe CW propagation	Dr. H. Whale G. H. Spaid J. E. Jackson	GSFC GSFC GSFC	Probe achieved altitude of 4261 miles and transmitted good data. Electron density was obtained to about 1500 miles, making the first time such measurements have been taken at this altitude. Weight: 94 lb Power: Battery
471	525	R. Rados	Omni-directional radiometer Widefield radiometer experiment Scanning radiometer experiment TV camera systems (2)	V. Suomi Dr. W. Nordberg Dr. R. A. Hanel	U. of Wis. GSFC GSFC	Orbit achieved. All systems transmitting well. Tegea Kinoptic lens used on one camera; Elgeet lens on the other. Support to Project Mercury. Weight: 285 lb Power: Solar
343.5	369	Dr. John C. Lindsay Dr. John C. Lindsay	X-ray spectrometer 0.510 Mev gamma-ray monitoring; 20–100 kev x-ray monitoring; 1–8A x-ray monitoring Dust particle experiment Solar radiation experiment, solar ultraviolet Solar gamma rays, high energy distribution Solar gamma rays, low energy distribution Solar gamma rays, high energy distribution Neutron monitor experiment Lower Van Allen belt Emissivity stability of surfaces in a vacuum environment	Dr. W. Behring Dr. W. Neupert K. Frost W. White M. Alexander C. McCracken W. White Dr. K. Hallam W. White K. Frost J. R. Winkler L. Peterson M. Savedoff G. Fazio W. Hess S. Bloom G. Robinson	GSFC GSFC GSFC GSFC U. of Minn. U. of Rochester U. of Calif. U. of Calif. Ames Research Center	Orbit achieved. Experiments transmitting as programmed. All tracking and data operations ceased August 6, 1963. Weight: 458 lb Power: Solar
N/A	N/A 3910	John E. Jackson Dr. S. J. Bauer	CW propagation RF probe Ion traps	S. Bauer Dr. H. Whale R. Bourdeau E. Whipple J. Donley G. Serbu	GSFC GSFC GSFC	Afforded night-time observations. Characteristics of the ionosphere differ drastically from daytime state when the temperature of the ionosphere is much cooler. See P–21. Weight: 94 lb Power: Battery

Goddard Space Flight Center Satellites and Space

Designation	Date		Launch Vehicle and Site	Objectives	Instrumentation	Period Minutes
	Launch	Silent				
Ariel I International Satellite (S-51; U.K. 1)	April 26, 1962	Active	Delta AMR	Study ionosphere and cosmic-ray relation. Joint U.K.-U.S. effort. U.K. responsible for experiments and for data analysis and interpretation. U.S. (NASA-GSFC) responsible for: project management; providing spacecraft; integrating and testing all systems; launching; tracking and data acquisition.	Electron temperature and density sensors; ion mass sphere; solar radiation detectors, Lyman-alpha at 1216A: solar aspect meter; electron density sensors; x-ray counters; tape recorder.	100.9
Tiros V 1962A-alpha I (A-50)	June 19, 1962	Active	Delta AMR	Develop principles of weather satellite system; obtain cloud-cover data and radiation data for use in meteorology.	Two TV camera systems with tape recorders for recording remote picture areas, infra-red sensors, magnetic orientation control, horizon sensor, north indicator.	100.5
Telstar I	July 10, 1962	Active	Delta AMR	Joint AT&T-NASA investigation of wideband communications.	The system provides for TV, radio, telephone, and data transmission via a satellite repeater system.	157.8
Tiros VI (A-51)	Sept. 18, 1962	Active	Delta AMR	Study cloud-cover and earth heat balance; measure radiation in selected spectral regions as part of a program to develop meteorological satellite systems.	Two TV camera systems (78° and 104° lens), clocks and tape recorders for remote operation, infrared and attitude sensors, magnetic attitude coil.	98.73

Probe Projects as of December 1962—Continued

Orbital Elements		Project Manager and Project Scientist	Experiment	Experimenter	Affiliation	Remarks
Perigee (Statute miles)	Apogee) (Statute miles)					
242.1	754.2	R. C. Baumann (U.S.)	Electron temperature & density	Dr. R. L. F. Boyd Dr. A. P. Willmore	Univ. College London	Orbit achieved. All experiments except Lyman-alpha transmitting as programmed. First international satellite. Contains British experiments, launched by American Delta vehicle. Weight: 150 lb Power: Solar
		Robert E. Bourdeau (U.S.)	Ion mass composition & temperature	Dr. R. L. F. Boyd Dr. A. P. Willmore	Univ. College London	
			Solar Lyman-alpha emission measurement	J. A. Bowles Dr. A. P. Willmore	Univ. College London	
			X-ray emission	Dr. R. L. F. Boyd Dr. K. A. Pounds Dr. A. P. Willmore	Univ. College London Univ. of Leicester Univ. College London	
			Solar aspect measurement	J. Alexander Dr. P. J. Bowen	Univ. College London	
			Cosmic ray analyzer	H. Elliot Dr. J. J. Quenby A. C. Durney	Imperial College London	
			Ionosphere electron density measurement	J. Sayers	Univ. of Birmingham	
			Dutchman experiments	Dr. A. P. Willmore	Univ. College London	
367	604	R. Rados	TV camera systems (2)			Launched at a higher inclination (58°) than previous Tiros satellites to provide greater coverage. Time of launch chosen to include normal hurricane season for South Atlantic. IR sensor inoperative, all other systems transmitting well. Weight: 285 lb Power: Solar
592.6	3503.2	C. P. Smith, Jr.	Included electron detector for range 250,000—1 Mev; proton detectors in the following energy ranges: 2.5–25.0 Mev, 26.0–34.0 Mev, ranges greater than 50 Mev	Dr. W. Brown	BTL	Orbit achieved. Television and voice transmissions were made with complete success. Bell Telephone Laboratories provide spacecraft and ground stations facilities. Government to be reimbursed for cost incurred. Weight: 175 lb Power: Solar
425	442	R. Rados	TV camera systems (2)			Inclination 58.3°; velocity perigee 16,822; apogee 16,756. Medium-angle camera failed Dec. 1, 1962, after taking 1074 pictures. Weight: 300 lb Power: Solar

Goddard Space Flight Center Satellites and Space

Designation	Date		Launch Vehicle and Site	Objectives	Instrumentation	Period Minutes
	Launch	Silent				
Alouette Swept Frequency Topside Sounder (Canada) (S-27)	Sept. 29, 1962	Active	Thor-Agena PMR	Measure the electron density distribution in the ionosphere at altitudes between 180 miles and 620 miles. Study for a period of a year the variations of electron density distribution with time of day and with latitude, under varying magnetic and auroral conditions; and with particular emphasis on high latitude effects. Obtain galactic noise measurements, study the flux of energetic particles, and investigate whistlers.	A swept-frequency pulse sounder covering the frequency range 0.5 to 11.5 Mc. FM and PM telemetry systems. Two sets of sounder antennas, the longest measuring 150 feet.	105.4
Energetic Particles Satellite Explorer XIV (S-3a)	Oct. 2, 1962	Active	Delta AMR	Describe the trapped corpuscular radiation, solar particles, cosmic radiation and the solar winds; and correlate the particle phenomena with the magnetic field observations.	An octagon-walled platform, fabricated from nylon honeycomb and fiber glass, houses most of the instruments, experiments, and electronics. The transmitter is located in the base of the space craft. A magnetometer package containing three orthogonally mounted magnetometers and calibration coils is located on a boom forward of the platform. Telemetry is PFM and transmits continuously.	37 hours (2185 minutes)
Explorer XV (S 3-b)	Oct. 27, 1962	Active	Delta AMR	Study new artificial radiation belt created by nuclear explosions.	Similar to Explorer XII	5 hours (C. 315 min)
Relay (A-15)	Dec. 13, 1962	Active	Delta AMR	Investigate wideband communications between ground stations by means of low-altitude orbiting spacecraft. Communications signal to be evaluated will be an assortment of TV signals, multichannel telephony, and other communications. Measure the effects of the space environment on the system; to include radiation damage to solar cells and radiation flux density. Provide tests and demonstration of low-altitude communications satellite.	Spacecraft contains an active communications repeater to receive and retransmit communications between the U.S. and Europe, U.S. and South America, and Europe and South America; and an experiment to assess radiation damage to solar cells, and to measure proton and electron energy.	185.09

Probe Projects as of December 1962—Continued

Orbital Elements		Project Manager and Project Scientist	Experiment	Experimenter	Affiliation	Remarks
Perigee (Statute miles)	Apogee (Statute miles)					
620	638	John E. Jackson (U.S.)	Topside sounder			The Alouette I satellite is a project of the Canadian Defence Research Board. The project is part of NASA's Topside Sounder Program. This will be NASA's first satellite to be launched from the Pacific Missile Range. 80.84° inclination Alouette is first spacecraft designed and built by any other country than the U.S. and USSR.
			Energetic particle counters			Weight: 320 lb
			VLF receiver (whistler)			Power: Solar
175	61,226	Paul G. Marcotte	Cosmic ray experiment	Dr. F. McDonald	GSFC	Velocity of apogee 1507 mph, perigee 23,734 mph. Inclination to equator, 33°.
		Dr. Frank B. McDonald	Ion detector experiment	L. Davis	GSFC	Weight: 86 lb
			Solar cell experiment	G. Longanecker	GSFC	Power: Solar
			Probe analyses	M. Boder	Ames Research Center.	
			Trapped radiation experiment	B. O'Brien	St. U. of Iowa	
			Magnetometer experiment	L. Cahill	U. of New Hampshire.	
195	10,950	Dr. John W. Townsend	Electron energy distribution	W. Brown V. Desai	Bell Telephone Laboratories	Good data being received on artificial radiation belt.
		Dr. Wilmot Hess	Omnidirectional detector	Dr. C. McIlwain	U. of Calif.	Weight: 100 lb
			Angular distributor	Dr. W. Brown	Bell Telephone Laboratories	Power: Solar
			Directional detector	Dr. C. McIlwain	U. of Calif.	
			Ion-electron detector	L. Davis	GSFC	
			Magnetic field experiment	L. Cahill	U. of New Hampshire	
			Solar cell gauge	H. K. Gummel	Bell Telephone Laboratories	
819.64	4612.18	Joseph Berliner	Determine radiation damage to solar cells and semiconductor diodes	Dr. R. Waddell	GSFC	Orbit achieved. TV, telephone, teletype, facsimile and digital data transmissions made with satisfactory results.
		Dr. R. C. Waddell	Measure proton energy (2.5–25.0 Mev)	Dr. W. Brown	Bell Telephone Laboratories	Weight: 172 lb
			Measure electron energy (0.6–1.6 Mev)	Dr. W. Brown	Bell Telephone Laboratories	Power: Solar
			Measure integral omnidirectional proton flux energy (35.0–300.0 Mev)	Dr. C. McIlwain	U. of Calif.	
			Measure directional electron energy (0.25–1.0 Mev)	Dr. C. McIlwain	U. of Calif.	
			Measure directional proton energy (1.0–60.0 Mev)	Dr. C. McIlwain	U. of Calif.	

APPENDIX A

United States Launching Record*

Year	Earth Satellite Attempts		Escape Payload Attempts	
	Successful	Failed	Successful	Failed
1957	0	1	0	0
1958	5	8	0	4
1959	10	7	1	2
1960	16	12	1	2
1961	35	12	0	†2
1962	54	11	4	1
Total	120	51	6	11

*NOTES:

1. Information contained in this table is drawn from unclassified sources, and is believed to be complete and accurate in keeping with the definitions given below.
2. Numbers are given in terms of identified separate payloads placed in an earth orbit, or sent to the moon or into solar orbit. A few launchings have put up more than one payload; if these payloads were intended to separate from each other in flight, they were counted individually even though in a limited number of cases such separation failed to occur. A payload is defined as an object put into orbit or sent away from the earth to accomplish some specific research or application purpose and to return data to the earth. Typically, a payload transmits telemetry, but not always (e.g., Echo I carried only a radio beacon). Some rocket casings may carry radio beacons, but limited data return incidental to putting up a payload does classify these as payloads in their own right.
3. The sole criterion of success and failure used here is that of attaining an earth orbit, escape to the moon, or solar orbit as appropriate to the column indicated. (Some payloads reached orbit or escaped without returning as much data as planned; other payloads failed to reach orbit or escape, yet returned useful data at least briefly.)

† These failed to escape as intended, but did attain an earth orbit and are in those totals.

Appendix B

A CHRONOLOGY

1955

March

The Navy proposed a program for the launch of an elementary uninstrumented satellite in 2 or 3 years. This program, jointly developed with the Army, was known as Project Orbiter. It called for the use of the Redstone booster and Loki rockets (small solid-propellant rockets).

September

Project Vanguard was born when the Department of Defense (DOD) wrote a letter to the Secretary of the Navy authorizing him to proceed with the Naval Research Laboratory (NRL) proposal for launch of a satellite. This letter authorized the launch of at least one U.S. satellite in the International Geophysical Year (IGY), which was to end in December 1958. 9

1956

Spring

After the Vanguard vehicle was redesigned to accommodate a spherical payload, a plan was developed at NRL for seven test vehicles and six satellite-launching vehicles.

December

NRL Test Vehicle 0 (TV–0), a Viking rocket carrying no Vanguard components, was successfully fired in a test of range facilities, telemetry, and instrumentation. 8

1957

May

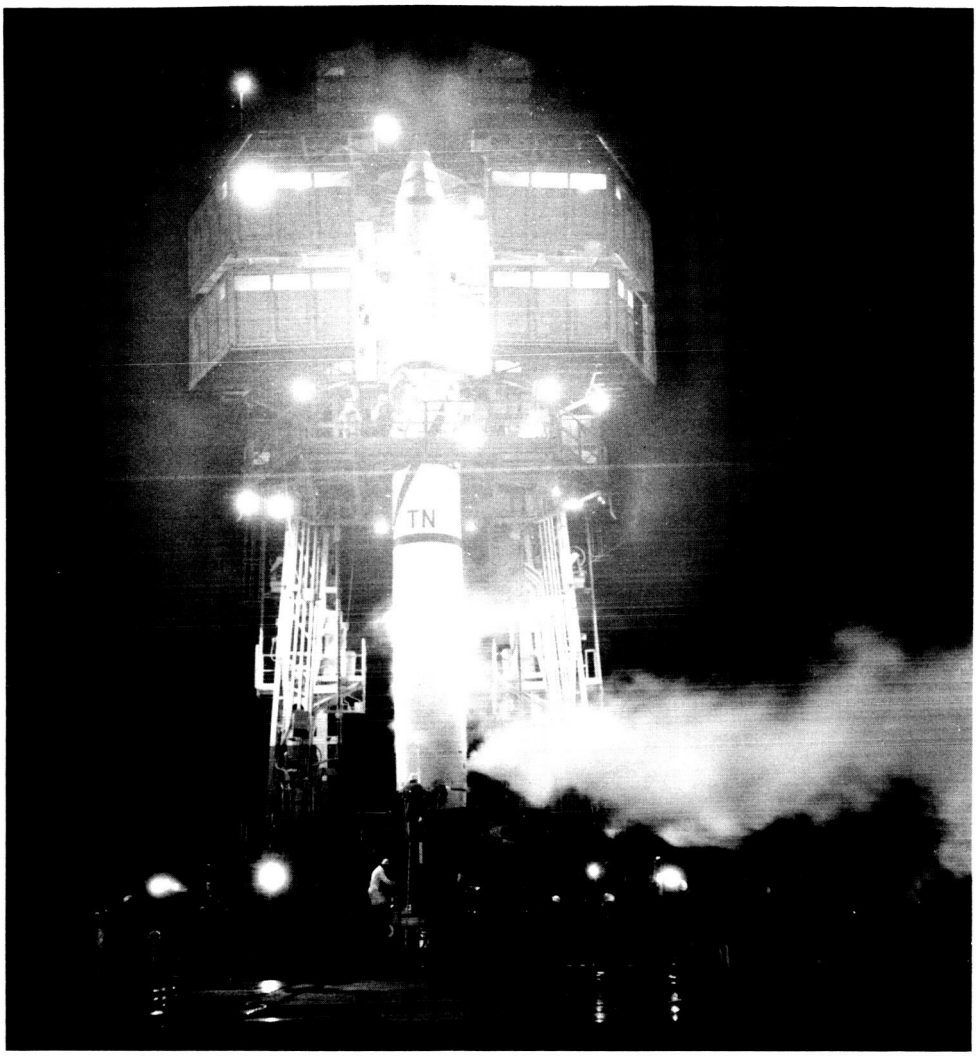
NRL TV–1, with a Viking first stage, launched a Vanguard third stage in a successful test of the control system and of the third-stage separation, spin-up, ignition, and propulsion. 1

October

Sputnik I (1957α2), the first manmade earth satellite, was launched by the USSR. It remained in orbit until January 4, 1958. 4

President Eisenhower, in a press release, congratulated the Soviet scientists on Sputnik I. He gave a brief history of the development of the U.S.–IGY satellite program and pointed to the separation of Project Vanguard from work on ballistic missiles. 9

The American Rocket Society presented to President Eisenhower a program for outer space research which proposed establishment of an Astronautical Research and Development Agency similar to the National Advisory 14



Launch of Redstone Missile.

1957 (Cont.)

October—Continued

Committee for Aeronautics and the Atomic Energy Commission, with responsibility for all space projects except those directly related to military defense.

23 The launch on this date of NRL TV–2 was the first successful launch of the complete Vanguard configuration—a successful test of the first-stage engine, control system, and vehicle structure; second and third stages were dummies. A 109-mile altitude was reached at 4250 mph.

November

7 President Eisenhower, in an address on science and security, announced that U.S. scientists had solved the problem of reentry and showed the nose cone of an Army Jupiter C missile which was intact after a flight through outer space.

13 President Eisenhower, in a speech on future security, proposed adoption of a formula for decisions on undertaking space projects which would include

1957 (Cont.)

November—Continued

the following criteria: "If the project is designed solely for scientific purposes, its size and its cost must be tailored to the scientific job it is going to do. If the project has some ultimate defense value, its urgency for this purpose is to be judged in comparison with the probable value of competing defense projects."

The National Advisory Committee for Aeronautics (NACA) authorized establishment of a special committee on space technology, headed by H. Guyford Stever. 21

December

The American Rocket Society's proposal for an Astronautical Research and Development Agency, which was presented to President Eisenhower on October 14, 1957, was announced publicly. 4

An attempt to launch NRL TV–3, the first test of the complete Vanguard vehicle and control system, failed when the first engine lost thrust after 2 seconds and the vehicle burned on the pad. This was the first Vanguard vehicle with orbit capability; it carried a 3.25-lb satellite with micrometer impact and geodetic measurement experiments. 6

1958

January

The American Rocket Society and the Rocket and Satellite Research Panel issued a summary of their proposals for a National Space Establishment. Preferably independent of DOD, but in any event not under one of the military services, this establishment would be responsible for the "broad cultural, scientific, and commercial objectives" of outer space research. 4

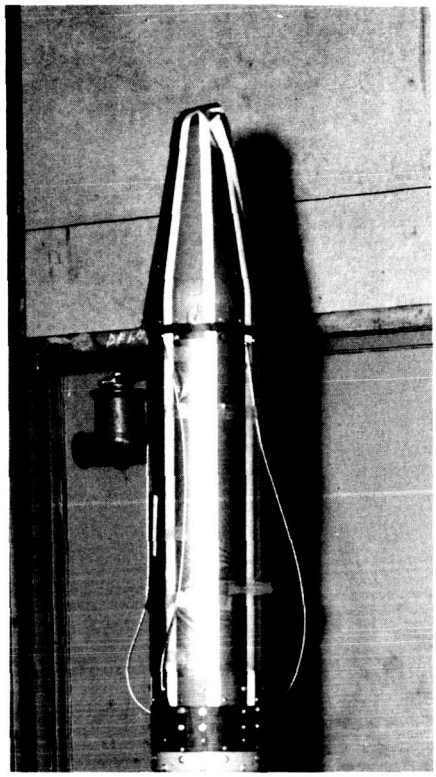
In his State of the Union message, President Eisenhower reported: "In recognition of the need for single control in some of our most advanced development projects, the Secretary of Defense has already decided to concentrate into one organization all antimissile and satellite technology undertaken within the Department of Defense." 9

In his budget message to Congress, President Eisenhower stated that in his request: "Funds are provided for an expanded research and development effort on military satellites and other outer space vehicles and on antimissile missile systems, to be carried out directly under the Secretary of Defense." 13

NACA adopted a resolution recommending that the national space program could be most effectively implemented by the cooperative effort of DOD, the National Academy of Sciences, the National Science Foundation and NACA, together with universities, research institutions, and industrial companies of the Nation. Military development and operation of space vehicles would be the responsibility of DOD, and research and scientific space operations the responsibility of NACA. 16

February

Explorer I (1958α1), the first U.S. satellite, was launched by a modified Army Ballistic Missile Agency–Jet Propulsion Laboratory Jupiter C, with the U.S.–IGY scientific experiment of James A. Van Allen, who discovered the radiation belt region around the earth. 1



Explorer I.

1958 (Cont.)

February—Continued

4 President Eisenhower directed James R. Killian, Jr., to head a committee to study and make recommendations on the governmental organization of the nation's space and missile program.

5 NRL TV–3 backup was a repeat of the TV–3 launch attempt on Dec. 6, 1957. It failed, however, with a control malfunction after 57 seconds of flight when the vehicle broke up at about 20,000 ft.

14 "Basic Objectives of a Continuing Program of Scientific Research in Outer Space," a report by the Technical Panel on the Earth Satellite Program of the National Academy of Sciences' IGY Committee was published. It proposed a program of space research extending beyond IGY.

March

17 The second U.S.–IGY satellite, Vanguard I (1958β2), was launched into orbit with a life expectancy of perhaps 1000 years. It was a highly successful scientific satellite which proved that the earth is slightly pear-shaped. Operating on solar powered batteries, it was still transmitting after 2 years in orbit.

26 The third U.S.–IGY satellite, Explorer III (1958γ1), another joint ABMA–JPL project, was successfully launched by an Army Juno II rocket. It yielded valuable data on the radiation belt region, micrometeorite impacts, and temperature before returning to the earth on June 27.

1958 (Cont.)

April

In a message to Congress, President Eisenhower proposed the establishment of a national aeronautics and space agency into which NACA would be absorbed. This agency was to have responsibility for civilian space science and aeronautical research. It would conduct research in these fields in its own facilities or by contract and would also perform military research required by the military departments. Interim projects pertaining to the civilian program which were under the direction of the Advanced Research Projects Agency (ARPA) would be transferred to this civilian space agency. 2

A proposal for a National Aeronautics and Space Agency, drafted by the Bureau of the Budget, was submitted to the U.S. Congress by the President. 14

NRL TV–5 failed to put its 21.5-lb spacecraft into orbit when the control system release failed and the third stage was not ignited. This IGY scientific spacecraft had radiation and environmental measurement experiments aboard. 28

May

Scientific findings from the two Explorer satellites (I and III) disclosed an unexpected band of high-intensity radiation extending from 600 miles above the earth to possibly 8000 miles. 1

Responsibility for the Project Vanguard portion of the U.S.–IGY scientific satellite program was transferred from the Navy to ARPA (also in the Department of Defense).

The first Vanguard satellite launch vehicle (NRL SLV–1) generally was successful with exception of second-stage burnout, which prevented achievement of satisfactory orbit. 27

June

The NRL SLV–2 launch failed when the second stage cut off prematurely, because of low chamber pressure, and terminated the flight. The satellite weighed 21.5 lb and was to have measured solar x radiation and environmental conditions. 26

July

Explorer IV (1958ε1), under the project direction of the DOD's Advanced Research Projects Agency (ARPA), was launched for the purpose of studying radiation belts detected by Explorers I and III and for the measurement of artificial radiation created by previous DOD experiments. 26

President Eisenhower signed the National Aeronautics and Space Act of 1958. In his statement he said: "The present National Advisory Committee for Aeronautics (NACA) with its large and competent staff and well-equipped laboratories will provide the nucleus for NASA." 29

August

Public Law 85–657 was approved authorizing appropriations to NASA for construction and other purposes and specifically for a "space projects center, in the vicinity of Washington, D.C.," a space projects building; research projects laboratory; posts and appurtenances; utilities; equipment and instrumentation, $3,750,000. 14

T. Keith Glennan was confirmed by the Senate as Administrator of the National Aeronautics and Space Administration (NASA). 15

1958 (Cont.)

August—Continued

19 T. Keith Glennan was sworn in as Administrator, and Hugh L. Dryden as Deputy Administrator. Forty days later, October 1, 1958, NASA was declared ready to function.

21 NACA held its final meeting and invited T. Keith Glennan, newly appointed Administrator of NASA.

September

24 First meeting of the newly created National Aeronautics and Space Administration (NASA) was held, with T. Keith Glennan as Administrator and Hugh L. Dryden as Deputy Administrator.

26 The third Vanguard satellite launch vehicle (SLV–3) reached an altitude of 265 miles, and was believed to have made one orbit and to have been destroyed 9200 miles downrange over Central Africa on reentry into the atmosphere.

October

1 By executive order of the President, DOD responsibilities for the remaining U.S.–IGY satellite and space probe projects were transferred to NASA; included were Project Vanguard and the four lunar probes and three satellite IGY projects which had previously been assigned by ARPA to the Air Force Ballistic Missile Agency and the Army Ballistic Missile Agency (ABMA). Also transferred were a number of engine development research programs. This was NASA's first official day.

21 Three weeks after NASA officially began operating, prospective contractors were invited to a briefing at NASA Headquarters on development of a 1.5-million-pound-thrust engine (Saturn).

November

7 A bidders' conference was held by NASA on a manned-satellite capsule for Project Mercury.

30 Mr. John T. Mengel was appointed Assistant Director, Tracking and Data Systems at the Beltsville Space Center (later the Goddard Space Flight Center). His background included physics and engineering, with 13 years experience at the Naval Research Laboratory.

During the Month NASA requested the highest priority (DX) for the Saturn engine project.

December

3 The President transferred the functions and facilities of the Jet Propulsion Laboratory (JPL) of the California Institute of Technology, Pasadena, California, from the Army to NASA.

NASA and the Army reached an agreement whereby the Army Ballistic Missile Agency (ABMA) and its subordinate organizations at Redstone Arsenal, Huntsville, Alabama, would be responsive to NASA requirements.

18 Project Score (1958ζ1), the third U.S.–IGY space probe—under the project direction of DOD's ARPA—was launched at 12:45 a.m., from the Atlantic Missile Range (AMR) by a Juno II rocket.

19 President Eisenhower's Christmas message was beamed from the Score satellite in orbit—the first voice beamed in from space.

1958 (Cont.)

December—Continued

IGY had been scheduled to close, but in October 1958 the International Council of Scientific Unions, meeting in Washington, approved extension of IGY through December 1959 under the name International Geophysical Cooperation–1959 (IGC–59), and also approved establishment of the Committee on Space Research (COSPAR) to continue international cooperation in the scientific exploration of space. 31

1959

January

NASA requested eight Redstone-type launch vehicles from the Army to be used in Project Mercury development. 8

February

NRL SLV–4, Vanguard II (1959α1), was successfully launched. It was a 21.5-lb satellite with infrared sensors for cloud-cover measurement. 17

NASA awarded $105 million in contracts for 1959 projects (15 satellites). 20

Discoverer I (1959 β1), a 1450-lb satellite, was successfully launched into a near-polar orbit by the Thor-Hustler booster from the Pacific Missile Range (PMR); stabilization difficulties hampered tracking acquisition. 28

March

Pioneer IV (1959ν1, the fourth U.S.–IGY space probe, a joint ABMA–JPL project under direction of NASA, was launched by a Juno II rocket from AMR and achieved an Earth-Moon trajectory, passing within 37,000 miles of the moon before going into a permanent solar orbit. Radio contact was maintained to a record distance of 406,620 miles. 3

NASA granted $350,000 to the National Academy of Sciences–National Research Council for a program of research appointments in theoretical and experimental physics to stimulate basic research in the space sciences. 11

NASA announced that Wallops Island, Va., had made 3300 rocket firings since 1945. 24

April

The first construction contract for the Beltsville Space Center was awarded. 10

The NRL SLV–5 launch failed when the second stage didn't operate properly and the vehicle tumbled. The 23.3-lb payload included a 13-in. ball with a magnetometer attached for mapping the earth's magnetic field and a 30-in. inflatable sphere to measure atmosphere drag. 13

Discoverer II (1959 γ1) was successfully placed into a polar orbit by the Thor-Agena A booster, but capsule ejection malfunctioned causing it to impact in the vicinity of the Spitsbergen Islands (Arctic Ocean) on April 14 instead of in the vicinity of Hawaii. It was the first vehicle known to have been placed in a polar orbit and was the first attempt to recover an object from orbit.

A NASA and DOD joint working group discussed procedures for search and recovery aspects of Project Mercury (manned space flights) involving Army, Navy, and Air Force units. 15

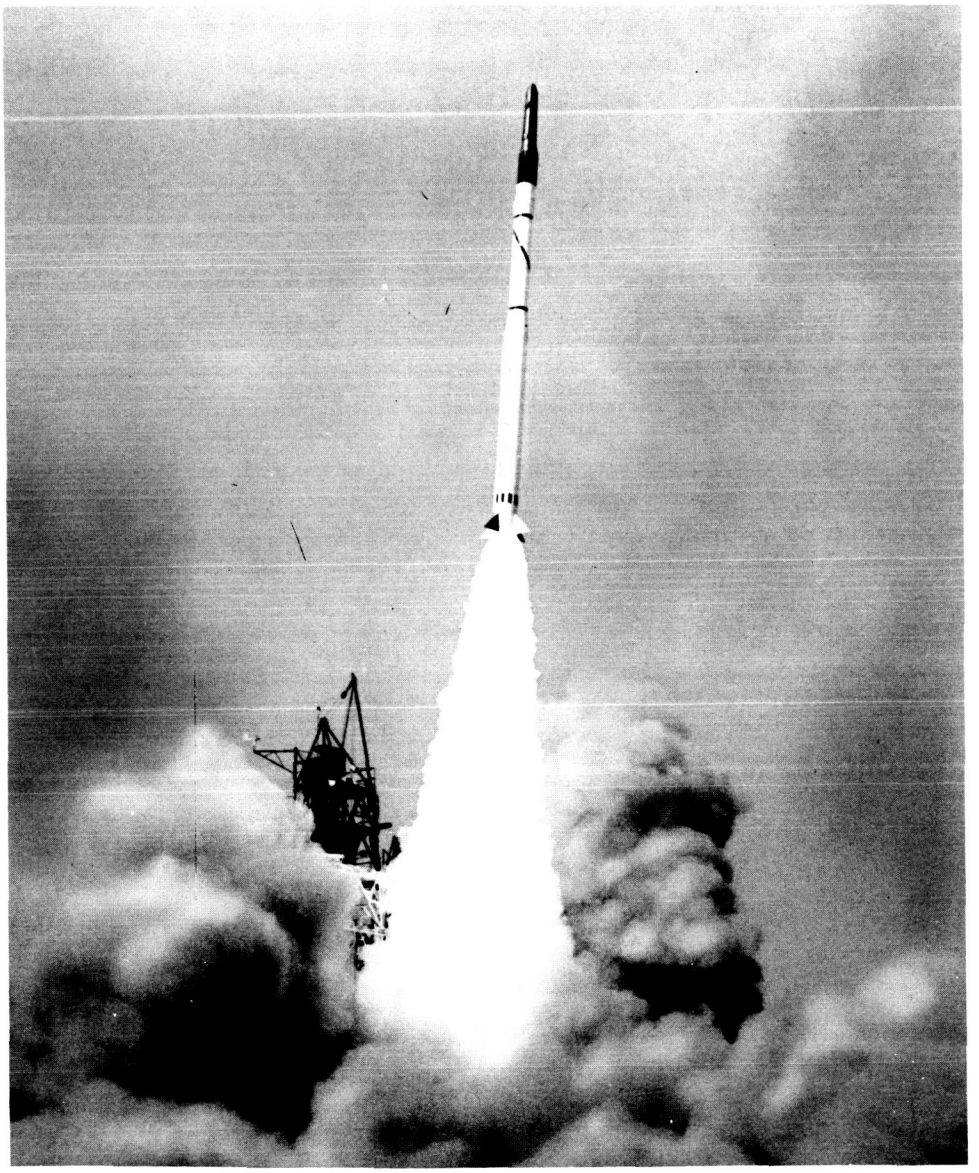
1959 (Cont.)

April—Continued

20 NASA announced acceptance of proposals by the Canadian Defence Research Telecommunications Establishment for continuing joint rocket and satellite ionospheric experiments of a nonmilitary nature.

24 Construction began at Goddard Space Flight Center on Buildings 1 and 2, the Space Projects Building and Research Projects Laboratory, respectively.

28 NASA announced the signing of a $24 million contract with Douglas Aircraft Company, Inc., for a three-stage Thor-Vanguard launching rocket called "Delta."



Sounding rocket fired at Wallops Island.

Building 1 under construction.

1959 (Cont.)

April—Continued

During the Month

The Tiros meteorological satellite program was transferred from DOD to NASA.

May

1

NASA's Administrator announced that the Beltsville Space Center was renamed "Goddard Space Flight Center," in commemoration of Dr. Robert H. Goddard, the American pioneer in rocket research. In the announcement John W. Townsend who was Chief of NASA Space Sciences Division and who earlier had served as Chief of Rocket Sonde Branch of the Naval Research Laboratory was named Assistant Director for Space Science and Satellite Applications. John T. Mengel who was responsible for the development of the Project Vanguard Minitrack System used for satellite tracking, was named Assistant Director for Tracking and Data Systems. Robert R. Gilruth who had been Chief of the Pilotless Aircraft Research Division, Langley Research Center, was named Assistant Director for Manned Satellites. The three Assistant Directors reported to the Director of Flight Development, NASA Headquarters, Dr. Abe Silverstein. The announcement also stated that the Office of Business Administration would be headed by Dr. Michael J. Vaccaro transferring from the NASA Lewis Research Center, Cleveland, Ohio, where he had served as Director of Organization and Personnel.

The Smithsonian Optical Tracking Station at Woomera, Australia, successfully photographed Vanguard I at the apogee of its orbit, nearly 2500 miles from the earth. This feat, which has been compared with taking a picture of a golf ball 600 miles away, was repeated on May 3 and 4.

6 (to June 25)

The Ad Hoc Committee on the Peaceful Uses of Outer Space of the United Nations met in session at U.N. Headquarters in New York City.

18

NASA announced formation of the Committee on Long-Range Studies headed by John A. Johnson to fulfill the charge of National Aeronautics and Space Act of 1958 (Sec. 102) calling for "establishment of long-range studies

1959 (Cont.)

May—Continued

of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes.

June

22 NRL SLV–6 failed when a second-stage malfunction allowed pressure to build up in the helium reservoir and caused a rupture about 40 sec after ignition. The 22.5-lb satellite was to have measured a solar–earth heating process.

July

7 A four-stage rocket with an Air Research and Development Command payload was fired from Wallops Island to an altitude of 750 miles. This was the first in a series of launchings to measure natural radiation surrounding the earth.

20 NASA selected the Western Electric Company to build its worldwide network of tracking and ground instrument stations to be used in Project Mercury.

August to December

A conference of the International Telecommunications Union which was held at Geneva, Switzerland, allocated radio frequency bands for space and earth–space use.

August

7 Explorer VI (1959δ1) was launched. All experiments performed; it provided the first complete televised cloud-cover pictures. A complete map of the Van Allen radiation belt region was obtained. *This was the first scientific satellite under the project direction of the Goddard Space Flight Center.*

14 While Explorer VI was passing over Mexico at an altitude of about 17,000 miles, it successfully transmitted a crude picture of a sunlit, crescent-shaped portion of the North Central Pacific Ocean. The area of the earth photographed was 20,000 square miles.

17 The first of the Nike-Asp sounding rockets, which were to provide geophysical information on wind activity between 50 and 150 miles high, was launched successfully from Wallops Island.

September

1 Dr. Harry J. Goett was appointed Director of GSFC. Dr. Goett came directly from the NASA Ames Research Center, Moffett Field, California, where he had been Chief of the Full Scale and Flight Research Division since 1948.

16 Building 2, the Research Projects Laboratory, was fully occupied.

18 Vanguard III (1959η1) was successfully launched. It had a 50-lb payload which measured the earth's magnetic field, solar x rays and space environmental conditions. This vehicle was SLV–7, the TV–4 backup vehicle, and had a more powerful third stage than previous Vanguards.

21 Construction began on Building 3, the Central Flight Control and Range Operations Building, at GSFC.

Vanguard vehicle in a gantry.

1959 (Cont.)

October

Explorer (1959*ι*1), the seventh and last U.S.–IGY earth satellite, under the direction of NASA with the Army as executive agent, was launched into an earth orbit by a modified Army Juno II booster. — 13

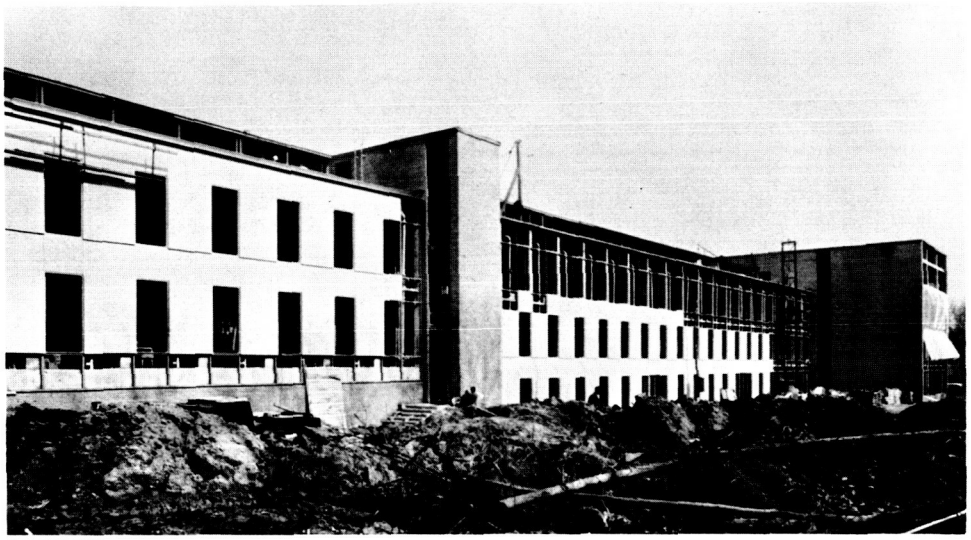
Russia's Lunik III (1959*θ*1) provided man's first look at the dark side of the moon, two weeks after launch, by transmitting automatically taken pictures. — 18

A 100-foot-diameter inflatable sphere was launched on a suborbital test flight from Wallops Island, to an altitude of 250 miles by the first Sergeant–Delta rocket; it was an aluminum-coated Mylar-plastic sphere, of the type to be used as a passive electronic reflector in the Echo satellites. — 28

Mr. Leopold Winkler was appointed Chief of Technical Services at GSFC. He had been engaged in engineering and design work at NRL since 1947. — During the Month

December

The Administrator of NASA, T. Keith Glennan, offered the services of the U.S. worldwide tracking network in support of any manned space flight the — 7



Building 2 under construction.

1959 (Cont.)

December—Continued

USSR might plan to undertake, in a speech before the Institute of World Affairs in Pasadena, Calif.

16 The transmitters of Vanguard III, launched on September 18, became silent after providing tracking signals and scientific data for 85 days. The satellite was expected to remain in orbit 40 years.

22 In a Canadian-U.S. cooperative project, NASA launched a four-stage Javelin sounding rocket from Wallops Island to measure the intensity of galactic radio noise.

31 Approximately 300 research rockets were launched during the 30-month IGY and IGC–59 periods; 221 of these had been launched during IGY.

1960

January

14 The President directed NASA Administrator Glennan to examine the need for additional money for high-thrust launching vehicles, which resulted in a NASA request for an additional $113 million for its 1961 fiscal year budget.

20 NASA presented its Ten-Year Plan of space activities to Congress; the plan included 25 major vehicle launchings per year, of increasing mission capability as research and development programs proceed.

February

7 New Explorer VII data showed that outer Van Allen belt rim moved north and south as much as 500 miles in latitude and varied tenfold in intensity within a few hours.

27 A 100-foot-diameter inflatable sphere was launched on the third suborbital test of this type, from Wallops Island, to an altitude of 225 miles.

1960 (Cont.)

March

Pioneer V (1960α1), a space probe, was successfully launched by Thor–Able, the start of an historic flight to measure radiation and magnetic fields in space and to communicate over great distances. 11

Pioneer V transmitted radio signals from a distance of more than 409,000 miles—a new record. 13

Vanguard I was in orbit and still transmitting on its second anniversary after traveling 131,318,211 miles. NASA reported that its orbit was being altered by solar pressure. 17

Pioneer V reported on command at 2 a.m., 1,002,700 miles away, transmitting seven kinds of scientific readings. 18

Pioneer V signals were received 2,000,000 miles from the earth. 24

April

Tiros I (1960β2), the world's first known weather observation satellite, was launched into orbit by Thor-Able and took pictures of the earth's cloud cover on a global scale from about 450 miles above the surface. 1

Fourth suborbital test of the 100-foot-diameter sphere was launched from Wallops Island to an altitude of 235 miles.

NASA fired the first of five Aerobee-Hi sounding rockets from Wallops Island in a program to measure ultraviolet radiation. 23

A NASA press conference with participating scientists reported on correlation of data from Explorers VI and VII and Pioneer V during a solar storm on March 31. 29

May

A 150-watt transmitter on Pioneer V, commanded at 5:04 a.m. EDT, worked satisfactorily at 8,001,000 miles from the earth. 8

Tiros I spotted a tornado storm system in the vicinity of Wichita Falls, Texas. 19

Construction started on Building 4, the Boiler House and Electric Substation, at GSFC; it houses service shops, a central powerplant, a refrigeration plant, and office areas. 23

NASA launched its 100-foot inflatable sphere to an altitude of 210 miles, to test a payload configuration carrying two beacon transmitters in a developmental flight of Project Echo. 31

NASA disseminated telemetry calibration for Explorer VII to members of the Committee on Space Research (COSPAR).

June

A 6-minute message was received by Jodrell Bank, England, from Pioneer V, the last communication received from this spacecraft, then 22.5 million miles from the earth, moving at a relative velocity of 21,000 mph. 26

The Smithsonian Institution posthumously awarded its highest honor, the Langley Medal, to Robert H. Goddard. 28

Building 1, the Space Projects Building at GSFC, fully occupied.

June to July

1960 (Cont.)

July

1 The first complete Scout rocket vehicle was launched from Wallops Island, but the fourth-stage separation and firing were not accomplished.

21 A Nike-Cajun sounding rocket was fired from Fort Churchill, Manitoba, Canada, containing an instrumental payload to measure data on energetic particles during a period of low solar activity.

August

3 The first Spaerobee rocket was launched from Wallops Island; a 56-lb payload was lifted to a 260-mile altitude.

12 Echo I (1960α1), the first passive communications satellite, was successfully launched into orbit; it reflected a radio message from President Eisenhower across the nation, thus demonstrating the feasibility of global radio communications via satellites. Echo I, visible to skywatchers, provided reflection for numerous long-range radio transmissions by private and government research agencies.

24 Echo I first went into the earth's shadow, with its two tracking beacons still operating. Since going into orbit on August 12, it had relayed hundreds of telephonic experiments and transmissions.

September

26 Heat balance between atmospheric pressure areas near the earth's surface and temperature readings in space were reported as a result of experiments in Explorer VII launched October 13, 1959, by Verner E. Suomi of the University of Wisconsin.

October

4 The second complete NASA Scout rocket was fired successfully to its predicted 3500-mile altitude and 5800-mile impact range, from Wallops Island.

12 NASA Administrator Glennan announced that communication satellites developed by private companies would be launched by NASA at cost to assist private industry in developing a communications network.

16 Mr. Eugene W. Wasielewski was appointed Associate Director of GSFC. He came from the Curtiss–Wright Corporation, Woodridge, N.J. From October 1947 to September 1956, he was at the NACA's Lewis Flight Propulsion Laboratory, Cleveland, Ohio.

November

3 Explorer VIII (1960ξ1) was launched. It measured the electron density, temperature, ion density and composition, and charge on the satellite in the upper atmosphere.

19 Construction began on Building 6, the Space Sciences Laboraory, at GSFC.

22 An Aerobee Hi was fired to a 105-mile altitude from Wallops Island, with four stellar spectrometers developed for an experiment by the University of Rochester's Institution of Optics.

23 Tiros II (1960π1) was launched by a Thor-Delta from AMR—the fourteenth successful U.S. satellite launch in 1960.

26 Construction began on Building 5, the Instrument Corporation and Installation Laboratory, at GSFC.

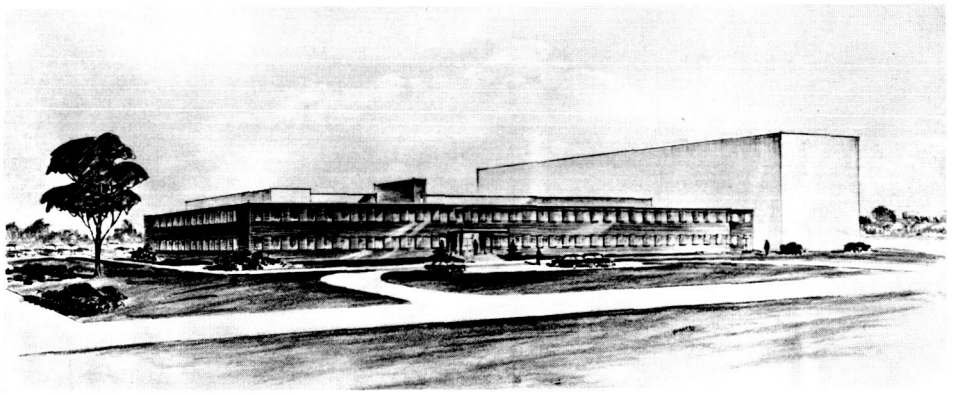
1961

January

30 — President Kennedy stated in his State of the Union address to Congress: "This administration intends to explore promptly all possible areas of cooperation with the Soviet Union and other nations 'to invoke the wonders of science instead of its terrors.' Specifically, I now invite all nations—including the Soviet Union—to join with us in developing a weather prediction program, in a new communication satellite program, and in preparation for probing the distant planets of Mars and Venus, probes which may some day unlock the deepest secrets of the universe."

31 — A contract was awarded for construction of Buildings 7 and 10, the Payload Testing Facility and Environmental Testing Laboratory at GSFC.

Experiments with Echo I were discontinued except for occasional checks, having provided innumerous communications since launch on August 12, 1960.



Architects's drawing of Buildings 7 and 10.

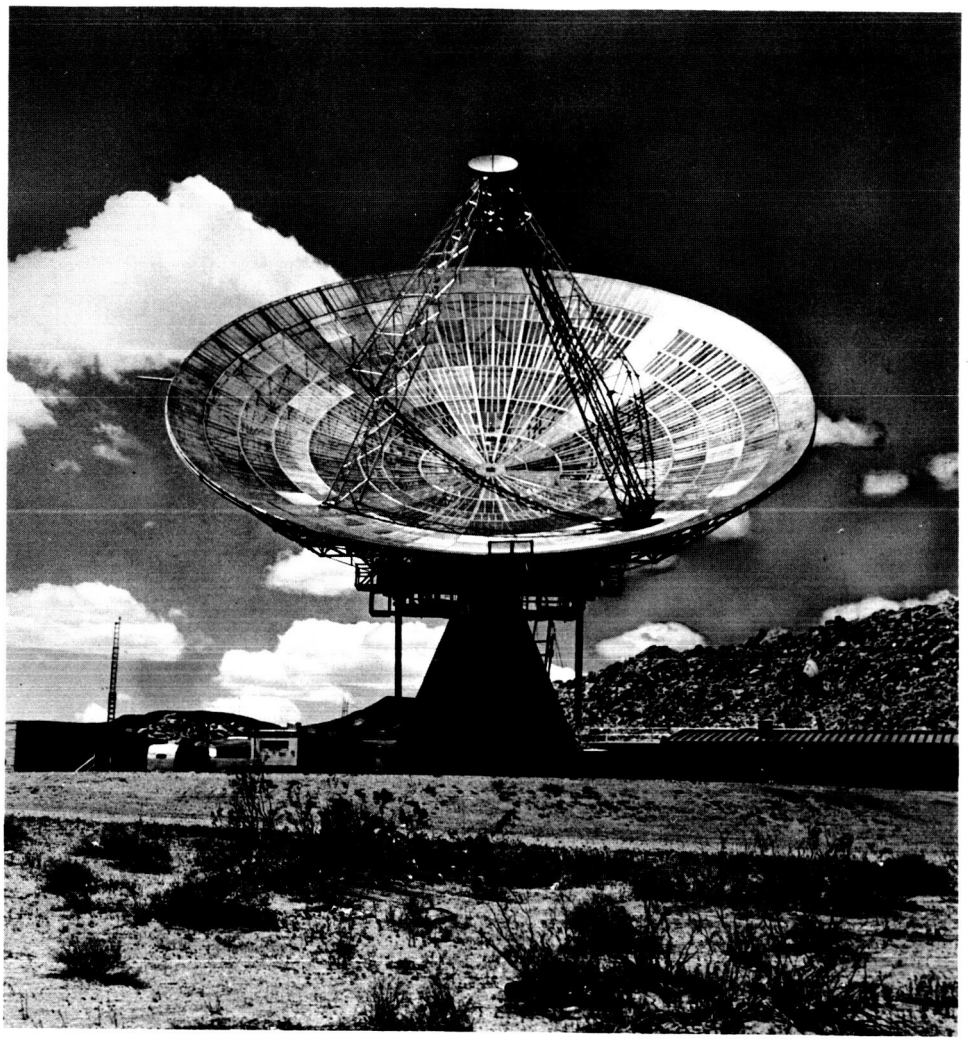
During the Month — The International Committee on Geophysics, successor organization to IGY, meeting in Paris, endorsed a proposal for the International Year of the Quiet Sun study during 1964 to 1965. (This period was selected since there would be intense sunspot activity.)

February

5 — The orientation of Tiros II made it impossible to obtain Northern Hemisphere pictures, and malfunctions made remote picture taking undesirable, so that use of the satellite's cameras was suspended until orbit precession again made Northern Hemisphere's pictures possible.

10 — A voice message was sent from Washington to Woomera, Australia, by way of the moon. NASA Deputy Administrator Dryden spoke on telephone to Goldstone, Calif., which "bounced" it off the moon to the deep space instrumentation station at Woomera. The operation was held as part of the official opening ceremony of the deep space instrumentation facility site in Australia.

10 to 11 — The Space Science Board of the National Academy of Sciences recommended that "scientific exploration of the Moon and planets should be clearly stated as the ultimate objective of the U.S. space program for the foreseeable future." This was submitted to the President on March 31 and was released publicly on August 6.



Antenna at Goldstone, California.

1961 (Cont.)

February—Continued

15 James E. Webb was sworn in as NASA Administrator.

16 Explorer IX (1961 δ1), a 12-ft inflatable sphere of Mylar and aluminum, painted with white "polka dots" was placed in orbit by a four-stage Scout booster from Wallops Island. This was the first satellite launching from Wallops and the first satellite boosted by a solid-fuel rocket.

France and NASA agreed to establish a joint program to test communications satellites to be launched by NASA in 1962 and 1963 in Projects Relay and Rebound.

17 Explorer IX was located in orbit by visual and photographic means after failure of its radio beacon delayed orbit confirmation.

NASA negotiated a $400,000 contract with G. T. Schjeldahl Co. to design, develop, fabricate, and test nine rigidized inflatable spheres for Project Echo, the passive communications satellite program.

1961 (Cont.)

February—Continued

NASA Administrator James E. Webb and Deputy Secretary of Defense Roswell Gilpatric signed a letter of understanding confirming the national launch vehicle program, the integrated development and procurement of space boosters by DOD and NASA. It was agreed that neither DOD nor NASA would initiate the development of a launch vehicle or booster for use in space without the written acknowledgment of the other agency. — 23

Tiros II completed 3 months in orbit, continuing useful observations beyond the original estimate of useful life.

A memorandum of understanding betwen the Federal Communications Commission (FCC) and NASA for delineating and coordinating civil communication space activities was signed. It stated that "earliest practicable realization of a commercially operable communications satellite system is a national objective." — 27

March

The installation of computer equipment was completed in Building 3 at GSFC. — 1

Direct-mode pictures by the Tiros II camera were resumed after a month of inoperation. The quality of the pictures showed slight improvement supporting the theory that foreign matter may have deposited on the lens and was gradually evaporating. — 6

The United Kingdom and the United States signed a formal agreement covering Project Mercury tracking stations on Bermuda. — 14 to 15

Up to this time, approximately 78 percent of the wide-angle photographs relayed from Tiros II were considered usable for current weather analysis. — Mid-Month

The Robert H. Goddard Space Flight Center was officially dedicated at Greenbelt, Md.; the dedication address was delivered by Dr. Detlev Bronk, President of the National Academy of Sciences. It was the 35th anniversary of Dr. Goddard's successful launching of the world's first liquid-fuel rocket. Mrs. Goddard accepted the Congressional Medal honoring her husband. — 16

Vanguard I had completed its third year in orbit and was still transmitting. It had provided much useful data on orbits, including the slight pear-shape of the earth and the effect of solar pressure. The Vanguard vehicle also provided the second stage for the Able, Delta, and Able-Star, as well as the third stage of Scout, pioneering solid-propellant stages used in Polaris and Minuteman. — 17

Problems with the shutter of the wide-angle camera of Tiros II were noted, but later disappeared and did not significantly affect data from this camera. — 19

Representatives of the French Committee for Space Research and NASA agreed on a cooperative space science program in a meeting at Washington, D.C. — 20 to 21

Tiros II had completed 4 months in orbit and continued to provide useful cloud picture and radiation data. A signal from Tiros II was used on orbit 1763 to trigger dynamite to break ground for new RCA Space Environment Center at Princeton, N.J. — 24

A Thor-Delta fired Explorer X (1961κ1) into a highly elliptical orbit (apogee of 186,000 miles, perigee of 100 miles) with instruments to transmit data on the nature of the magnetic fields and charged particles in the region of space where the earth's magnetic field merges with that in interplanetary space. — 25

1961 (Cont.)

March—Continued

27 Its instruments recording a magnetic impulse, Explorer X became the first satellite to measure the shock wave generated by a solar flare.

28 GSFC scientists reported that Explorer X had encountered magnetic fields considerably stronger than expected in its elongated orbit which carried it 186,000 miles from the earth (almost halfway to the moon), although it would take several weeks to analyze acquired data.

31 NASA selected General Electric's Space Sciences Laboratory and Avco Corp. for negotiation of contracts to study the feasibility of a magneto-gas dynamic electric rocket or thermal arc jet rocket engines.

By this date, all stations of NASA's worldwide Mercury tracking network were operational.

April

12 President Kennedy, in his regular press conference, stated that "no one is more tired than I am" in seeing the United States second to Russia in the space field. They secured large boosters which have led to their being first in Sputnik, and led to their first putting their men in space. We are, I hope, going to be able to carry out our efforts, with due regard to the problem of the life of the men involved, this year, but we are behind . . . the news will be worse before it is better, and it will be some time before we catch up. . . ."

19 Preliminary data from Explorer X indicated that solar winds blow the sun's magnetic field past the orbit of the earth.

27 Explorer XI (1961ν1) was launched. It detected gamma rays from space and directional flux.

May

1 Tiros operations at Belmar, N.J., were terminated to begin the move of equipment to Wallops Island.

18 The first test inflation of a 135-foot rigidized inflatable balloon in a dirigible hangar was conducted by NASA Langley Research Center and G. T. Schjeldahl Co. at Weeksville, N.C.

The GSFC Institute for Space Studies in New York announced that its first major project, a 2-month seminar on the origin of the solar system, would be held in the fall of 1961.

22 Construction began on Building 7, the Payload Testing Facility at GSFC.

23 Tiros II completed 6 months in orbit, having transmitted over 31,000 photographs of which more than 75 percent have been classified as fair to good for meteorological analysis.

The discussion "Workshop: Telemetry in Europe" at the National Telemetering Conference in Chicago brought seven European representatives together with American scientists in working out unofficial preliminary standardization planning on bands, means, and frequencies.

24 The FCC endorsed the ultimate creation of a commercial satellite system to be owned jointly by international telegraph and telephone companies and announced a meeting for June 5 to explore "plans and procedures looking toward early establishment of an operable commercial communications satellite system."

Dr. Robert Jastrow addresses the Conference on Origins of the Solar System held shortly after the Institute for Space Studies began operation in New York City.

1961 (Cont.)

May—Continued

In his second State of the Union message President Kennedy reported to Congress regarding the space program: "With the advice of the Vice President, who is Chairman of the National Space Council, we have examined where we (United States) are strong and where we are not, where we may succeed and where we may not. . . . Now it is time to take longer strides—time for a great new American enterprise—time for this Nation to take a clearly leading role in space achievement which in many ways may hold the key to our future on earth." President Kennedy set forth an accelerated space program based upon the long-range national goals of landing a man on the moon and returning him safely to earth; early development of the Rover, a nuclear rocket; speed-up of the use of earth satellites for worldwide communications; and providing "at the earliest possible time a satellite system for worldwide weather observation." An additional $549 million was requested for NASA over the new administration's March budget requests; $62 million was requested for DOD for starting development of a solid-propellant booster of the Nova class. (Nova will be capable of placing 100,000 lb on the moon; its first stage will have six 1,500,000-lb-thrust engines.) **25**

Also, on May 25th, a prerecorded voice message was successfully transmitted from NRL to the Bell Telephone Laboratories via Echo I, the quality of the transmission being virtually as good as in previous experiments.

The First National Conference on the Peaceful Uses of Space was held at Tulsa, Okla. Leading American space scientists and technologists appraised the current and future applications of space science and technology for human welfare. It was sponsored by the Tulsa Chamber of Commerce and **26 to 27**

1961 (Cont.)

May—Continued

NASA, with the Aerospace Industries Association, Aerospace Medical Association, American Astronautical Society, American Institute of Biological Sciences, American Rocket Society, Electronic Industries Association, Frontiers of Science Foundation (Oklahoma); and Institute of the Aerospace Sciences as cosponsors.

June

8 NASA announced accelerated recruiting of qualified scientists and engineers at its field centers to fill anticipated manpower requirements in the expanded space exploration program. During 1960 NASA had interviewed 3000 persons on 100 college campuses.

Astronomers of Lick Observatory positioned a 36-inch refractor telescope to intersect the path of Echo I at its predicted point of maximum elevation. The prediction of GSFC was confirmed at the exact time and within 10 minutes of arc.

9 A NASA press conference revealed that data from Vanguard III (November 15 to 17, 1960) and Explorer VIII (also during November 1960) indicated that high-velocity clouds of micrometeorites moved near the earth, perhaps in a meteor stream around the sun. These new data had just been from discovered from completed analysis.

Echo I completed its orbit 3697 after 9 months in orbit. When this first passive communications "balloon satellite" was launched on August 12, 1960, it was not expected to have a long life span.

14 The Argentine Comision Nacional de Investigaciones Espaciales and NASA signed a memorandum of understanding for a cooperative space science research program using sounding rockets.

A four-stage Javelin fired to 560-mile altitude from Wallops Island tested the extension of two 75-foot antenna arms on radio command, a test flight in the Canadian–U.S. Alouette satellite program.

15 President Kennedy directed the National Aeronautics and Space Council to undertake a full study of the Nation's communications satellite policy; he stated that leadership in science and technology should be exercised to achieve worldwide communications through the use of satellites at the earliest practicable date. The President said that, although no commitments as to an operational system should be made, the Government would "conduct and encourage research and development to advance the state of the art and to give maximum assurance of rapid and continuing scientific and technological progress."

23 Tiros II completed 7 months in orbit, still providing useful data.

During the Month NASA entered a letter contract with RCA for four additional Tiros weather satellites.

July

1 The Weather Bureau announced that cloud-cover pictures taken by Tiros I went on public sale at the National Weather Records Center, Asheville, N.C.

9 The National Science Foundation released a forecast of the Nation's science needs for the next decade, which predicted that the United States would need nearly twice as many scientists in 1970 (168,000) as today (87,000).

1961 (Cont.)

July—Continued

12 The Tiros III (1961ρ1) weather satellite was successfully launched into a near-circular orbit by the Thor-Delta booster from Cape Canaveral.

13 to 14 Two Nike-Cajun rockets launched University of New Hampshire–GSFC payloads from Wallops Island.

19 Tiros II photographed tropical storm Liza in the Pacific Ocean, pinpointing its location for meteorologists.

Italy and the Mediterranean as seen from a Tiros satellite.

23 NASA Administrator Webb, in Congressional testimony, pointed out that the Tiros cloud-cover program was known to the entire world, involved no surveillance, and promised great benefits to all nations. He pointed out that data from the Tiros satellites had been made available to all, including the Soviet Union.

28 NASA and AT&T signed a cooperative agreement for the development and testing of two, possibly four, active communications satellites during 1962. AT&T would design and build the TSX satellites at its own expense, and would

1961 (Cont.)

July—Continued

reimburse NASA for the cost of the launchings by Thor-Delta vehicles at Cape Canaveral. The relation between this contract and the overall NASA communications satellite program, aimed at early development of an operational system, was explained at a NASA press conference.

29 The Chief of the Japanese Weather Bureau, Kiyoo Wadachi, reported that 30 observations from Tiros III had been received from the United States.

31 Tiros II transmitted a photograph of a major storm off the south tip of Africa. Launched on November 23, 1960, Tiros II had been expected to have a useful lifetime only of about 3 months.

NASA awarded a contract to the University of Michigan to continue to provide research instrumentation for measurement of temperatures and winds at altitudes up to 150 km with Nike–Cajun and other sounding rockets.

August

3 Tiros II transmitted a photograph of a major storm in the northwest Pacific Ocean.

8 Over 100 foreign weather services were invited by NASA and the U.S. Weather Bureau to participate in the Tiros III experiment for a 9-week period beginning today. The program provided cooperating services with an opportunity to conduct special meteorological observations synchronized with passes of the satellite.

11 NASA announced negotiation of a contract with Hughes Aircraft Co. for construction of three experimental synchronous communications satellites (Syncom).

12 Echo I completed its first year in orbit, still clearly visible to the naked eye, after traveling 4480 orbits and 138 million miles. Echo I had provided the basis for over 150 communications experiments, recent ones indicating only a 40-percent reduction in transmission reflection caused by the changed shape. It also provided significant data on atmospheric drag and solar pressure.

Aerobee 150A, with a liquid-hydrogen experiment, was fired from Wallops Island.

15 Explorer XII (1961υ1) was placed into a highly eccentric orbit, by a Thor–Delta booster from AMR, to provide detailed evaluation of the behavior of energetic particles between a 180- and 47,800-mile altitude. Under GSFC this "windmill" satellite carried six experiments developed by Ames Research Center, State University of Iowa, University of New Hampshire, and GSFC. Several days were required to confirm the orbit. All instrumentation operated normally.

17 NASA announced that Explorer XII had successfully completed its first orbit and was sending data on magnetic fields and solar radiation from an apogee near 54,000 miles and a perigee within 170 miles of the earth.

Tiros III spotted two storm cells about 500 miles south and southwest of Hawaii; reports alerted Honolulu and Guam of these previously unknown potential typhoons.

1961 (Cont.)

August—Continued

NASA held a news conference on Explorer XII, at which the great amount of continuous coverage on interrelated data in its eccentric orbit was pointed out. — 21

Explorer XIII (1961κ1) was placed into orbit by the Scout rocket from Wallops Island; it was a micrometeorite counting satellite developed by the Langley Research Center and GSFC. — 25

NASA announced that Explorer XIII had reentered the atmosphere. Transmitting considerable data on micrometeoroids, the spacecraft was last heard on August 27 by the Minitrack facility at Antofagasta, Chile. — 29

With the successful launch of Explorer XII on August 15, the Delta launch vehicles had successfully launched five satellites in six attempts, the only failure being the first attempt. Delta's high reliability record began with Echo I on August 12, 1960, and included Tiros II and III, and Explorers X and XII. Built by prime contractor Douglas Aircraft, the NASA Delta launch vehicle consists of a Thor first stage (Rocketdyne MB–3 liquid fuel engine), Aerojet–General second stage (AJ–10–118, an improved Vanguard second stage), and an Allegany Ballistics Laboratory third stage (X–248 rocket spin-stabilized version of the Vanguard third stage). — During the Month

September

Tiros III photographed Hurricane Esther in the process of formation, 2 days before hurricane-hunter aircraft verified winds of hurricane force. However, the quality of the Tiros III pictures, processed in 8 hours through the National Meteorological Center, Suitland, Md., were not alone sufficient for identification of the hurricane. — 10

On the same day, Tiros III also observed one-eighth of the earth, providing data on two other active hurricanes (Carla and Debbie), one dissipating hurricane (Betsy), two typhoons (Nancy and Pamela), and at least one other vortex storm.

Two experiments to measure atmospheric winds, temperature, and density in relatively high altitudes were conducted from Wallops Island in two four-stage Argo D–4 rocket launches. Sodium clouds were released at near 120 statute miles and again at 228 miles in the first launch, and at 118 and 230 miles in the second launch. French scientists participated by using special optical instruments to observe the brilliant orange and yellow clouds which stirred a rash of public inquiries from hundreds of miles. — 13

Construction began on Building 8, the Satellite Systems Laboratory at GSFC. — 16

In a stirring address to the Assembly of the United Nations meeting in New York, President Kennedy called for "world law in the age of self-determination" rather than a "world war in the age of mass extermination." Among basic proposals for waging effective peace, he urged "keeping nuclear weapons from seeding new battlegrounds in outer space," in projecting the theme that "the events and decisions of the next 10 months may well decide the fate of man of the next 10,000 years." — 25

1961 (Cont.)

September—Continued

28 to 29 — A pair of spin-up rockets on Tiros II successfully fired after more than 10 months in orbit.

During the Month — Congress appropriated funds to the U.S. Weather Bureau for implementation of the National Operational Meteorological Satellite System. To phase in as early as technology warrants and to continue expanding the operational capability through the early Nimbus (advanced weather satellite) launchings by NASA, the system was planned to be fully operational by 1966, when the Nimbus system would become operational. The system would include data acquisition stations in northern latitudes, communications for transmitting the data, and a National Meteorological Center to receive, process, analyze, and disseminate the derived information over domestic and international weather circuits.

October

11 — The final report of House Committee on Science and Astronautics relating to their hearings on "Commercial Applications of Space Communications Systems" was released, having among its conclusions:

(1) Because of the worldwide interest and potential usefulness of a space communications system, the U.S. Government must "retain maximum flexibility regarding the central question of ownership and operation of the system."

(2) NASA will not only evaluate the various commercial proposals but will "conduct all space launches and retain direct control over all launching equipment, facilities, and personnel."

(3) Research and development of military space communications systems should continue to be conducted by DOD, but all research and development in space communications "should be conducted under the general supervision of NASA in accordance with its statutory mandate to plan, direct, and conduct aeronautical and space activities" as well as evaluate the technical merits of proposed systems.

13 — The Ad Hoc Carrier Committee established by FCC to make an industry proposal on the development and operation of commercial communications satellites recommended a nonprofit corporation be formed, to be owned by companies engaged in international communications, with the U.S. Government having one more representative on the board of directors than any single company. Western Union filed a minority statement proposing a public stock company arrangement to prevent dominance of the corporation by any one company.

After its second year, Explorer VII was still transmitting, although it had been scheduled to stop a year ago.

14 — An Argo D–4 launched from Wallops Island carried a Canadian–U.S. topside sounding satellite payload to 560-mile altitude.

19 — P–21, the Electron Density Profile Probe, was launched, with good data received. Electron density measurements were obtained to about 1500 miles, a new "first."

Construction began on Building 10, the Environmental Testing Laboratory at GSFC.

1961 (Cont.)

October—Continued

NASA announced that it had ordered 14 additional Delta launch vehicles for Relay, Syncom, Telstar, and Tiros satellites. **23**

GSFC and the Geophysics Corp. of America launched a Nike-Cajun rocket from Wallops Island with a 60-lb payload that reached a 90-mile altitude in a study of electron density and temperature in the upper level of the atmosphere. **27**

NASA announced that the first Mercury-Scout launch to verify the readiness of the worldwide Mercury tracking network would take place at AMR. **29**

November

The Bell Aerosystems Co. announced the design of a "practical zero gravity belt" to propel a man a short distance in space. **12**

Tiros II had completed its first year in orbit, still transmitting cloud-cover photographs of usable quality, although it had been expected to have a useful lifetime of only 3 months. Tiros II had completed 5354 orbits and had transmitted over 36,000 photographs. **23**

Senator Robert Kerr announced that he would introduce legislation to authorize private ownership to the U.S. portion of the proposed worldwide communications satellite system. His bill would create the "Satellite Communications Corp." which the participating firms would buy into. **27**

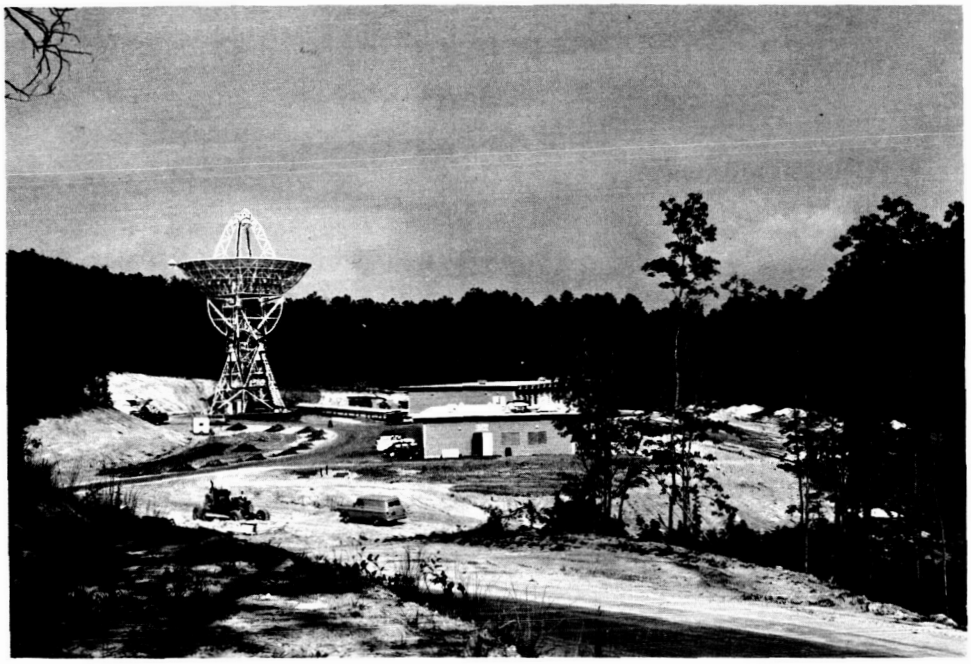
December

Explorer XII had returned voluminous data revising previous information on the Van Allen radiation belts and showing them to be no substantial problem to manned space flight. Launched on August 15, 1961, and transmitting until December 6, 1961, Explorer XII returned information amounting to 5636 telemetry tapes (2400 feet each). Of principal interest was its finding that the Van Allen belts have a 1000:1 preponderance of protons over electrons. Since the protons are of less than 1 Mev, they do not themselves offer a serious radiation problem and serve to slow the velocity of other radiation. **15**

Dr. Robert Jastrow, Chief of the Theoretical Division and Director of the Institute for Space Studies of GSFC, making the 25th annual Wright Brothers' Lecture before the Institute of Aerospace Sciences, reviewed progress in the space sciences and said that one of the most exciting and fruitful areas thus far had been investigation of "solar control over the atmosphere of the earth: the causes of weather activity in the lower atmosphere, and the structure of the upper atmosphere." **18**

NASA announced that the first station in a network of data-gathering stations for use with second-generation (advanced) satellites had been completed near Fairbanks, Alaska. The site for the second of the $5 million installations (each had a high-gain antenna 85 ft in diameter) was announced to be Rosman, N.C., 40 miles southwest of Asheville.

The West German Post Office indicated it would construct near Munich a ground station capable of handling up to 600 phone calls simultaneously for operations, in late 1963 or early 1964, with Telstar and Relay type satellites. **During the Month**



Rosman tracking facility.

1962

January

18 GSFC selected Rohr Aircraft Corp. to negotiate the manufacture and erection of three 85-foot-diameter parabolic antenna systems at Pisgah National Forest (Rosman, N.C.); Fairbanks, Alaska; and an undetermined location in eastern Canada.

19 At a NASA press conference, scientists described preliminary scientific results obtained by Explorer XII, based on a study of 10 percent of the data. It appeared that instead of the two radiation belts (previously called the inner and outer Van Allen belts) there was one magnetosphere extending roughly from 400 miles above the earth to 30,000 to 40,000 miles out.

23 GSFC announced the selection of Motorola, Inc., Military Electronics Division, of Scottsdale, Ariz., as contractor for research and development on the Goddard range and range-rate tracking system. Intended for tracking satellites in near-space and cislunar space, the system would measure spacecraft position to within a few feet and velocity to within fractions of a foot per second, by measuring carrier and sidetone modulations.

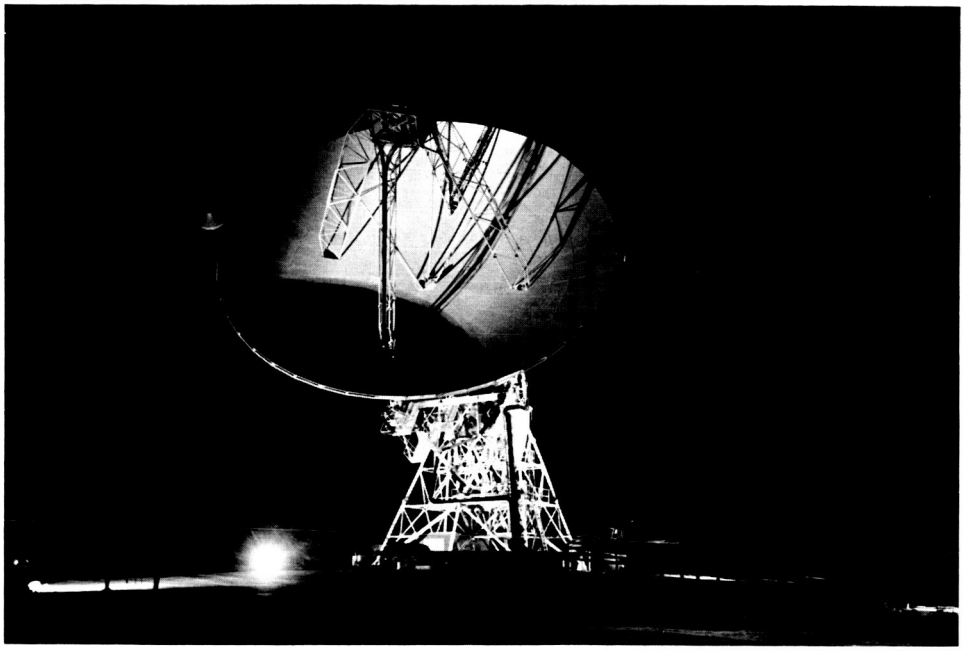
Dr. Sigmund Fritz of the Weather Bureau reported that Tiros III had spotted fifty tropical storms during the summer of 1961.

25 Explorer X detected a "shadow" on the side of the earth away from the sun; this shadow was marked by an absence of the solar wind, a belt of plasma moving out from the sun at about 200 miles/second but deflected around the earth by the earth's magnetic field and creating a cone-shaped "shadow" some 100,000 miles across at its larger end. The Explorer X findings were reported to the annual meeting of the American Physical Society in New York by Dr. Bruno Rossi of the Massachusetts Institute of Technology.

1962 (Cont.)

January—Continued

"Satellite Communications Corporation" bills were introduced by Senator Robert Kerr (S. 2650) and by Rep. George Miller (H.R. 9696), which would amend the NASA Act by adding a new section which would declare that it is "the policy of the United States to provide leadership in the establishment of a worldwide communications system involving the use of space satellites." The section would create a "Satellite Communications Corporation" which would be privately owned and managed, and which would develop and operate a communications satellite system. 25



Antenna at Rosman, North Carolina.

Explorer I had completed its fourth year in orbit and had a life expectancy of several more years. 31

The Nimbus meteorological satellite underwent a rigorous test program at General Electric's Missile and Space Vehicle Center, Valley Forge, Pa. During the Month

NASA awarded a contract to the Kollsman Instrument Division for a 38-inch-diameter primary mirror in the space telescope to be used in the Orbiting Astronomical Observatory (OAO).

February

Tiros IV (1962β1) was launched by a three-stage Thor-Delta rocket from Cape Canaveral into a near-circular orbit with an apogee of 525 miles and a perigee of 471 miles. It featured the same basic types of equipment as previous Tiros satellites, including cameras for cloud-cover photography and infrared sensors to measure temperatures at various levels in the atmosphere. The principal innovation was a camera with new type of wide-angle lens covering 8

an area 450 miles on a side, which was expected to provide minimum distortion. A NASA press conference reported that the quality of Tiros IV pictures was good.

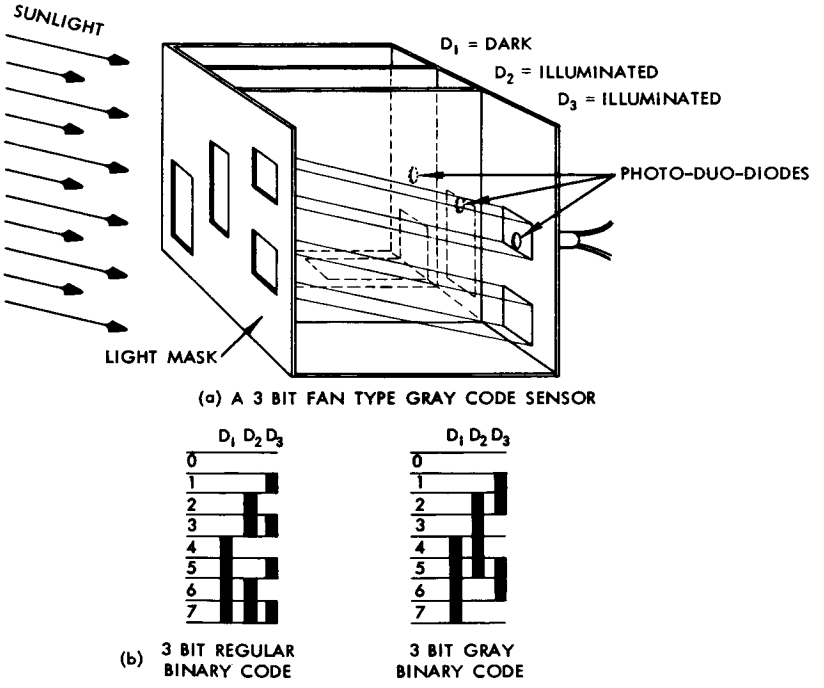
16 Explorer IX (1961δ1) was launched. The balloon and fourth stage orbited. Transmitter on the balloon failed to function properly and required optical tracking.

21 NASA announced plans to attempt to launch the 440-lb Orbiting Solar Observatory (OSO), containing 13 experiments, within a week.

22 The National Center for Space Studies of France, headed by Pierre Auger, released a summary of its 1962 space program: launching of sounding rockets carrying a rat and later a cat to 125 miles altitude; research observations of the sun and various planets; and telecommunications experiments. France would also cooperate in a joint satellite project with the U.S. and participate in the European Organization for Space Research.

25 Soviet scientists claimed to have discovered the third radiation belt around the earth and published such findings two years before the findings of Explorer XII were made public by NASA on January 19, 1962.

28 James S. Albus, an engineer at GSFC, was awarded $1000 for his invention of a digital solar aspect sensor.



The Digital Solar Aspect Sensor.

1962 (Cont.)

March

Tiros weather satellites had been of major assistance in improving weather forecasts for airline operations. Mr. Silvio Simplicio, supervising forecaster at New York International Airport, said: "We can do a job nowadays we never thought we could do years ago . . . With the aid of the Tiros satellites we never had it so good, and with the Nimbus meteorological satellite now undergoing tests, we expect even better results." 5

Morton J. Stoller, NASA's Director of Applications, testified before a subcommittee of the House Committee on Science and Astronautics that each of the series of weather satellite projects, Tiros, Nimbus, and Aeros, would not only provide an advance in capability but would extend observations into vital new areas. 6

OSO I, Orbiting Solar Observatory I (1962 ζ1) was successfully launched into orbit from Cape Canaveral, marking the seventh straight success for the Thor–Delta booster. 7

It was decided that the tracking network that operated during the Glenn orbital flight would for the most part be sufficient to handle the 18-orbit manned flights to follow, according to Edmond C. Buckley, NASA's Director of Tracking and Data Acquisition, in testimony before a subcommittee of the House Committee on Science and Astronautics. 8

NASA announced that Echo I, the 100-ft balloon-type passive communications satellite launched on August 12, 1960, had recently become increasingly difficult to see. The sphere now presented only ½ to ¼ its original size; this was due either to shrinkage or distortion during its 1½ years in orbit. 11

A press conference of Smithsonian Astrophysical Observatory and NASA scientists reported that Explorer IX, launched on February 16, 1961, had provided new and refined information on the density of the upper atmosphere. They confirmed a figure previously released—that the density of the atmosphere at 420 mi. was 3×10^{-17} gm/cm^3. Explorer IX density values were about 10 times lower than those computed in 1959 from earlier satellites. Most of this decrease was attributed to the decrease in solar activity since the peak of the solar cycle in 1958 and 1959. Changes were also clearly related to the 27-day rotational period of the sun and to the occasional violent solar storms that affect the earth's atmosphere. Explorer IX, a 12-ft aluminum-foil sphere painted with white "polka dots," was expected to have an orbital life of two more years. As it spiraled down into denser atmosphere, it was expected to provide much more information on density at altitudes down to 100 miles. 14

The National Rocket Club announced the establishment of the Dr. Robert H. Goddard Historical Essay Award, an annual competition in the history of rocketry and astronautics, the first such competition in the field of history.

Today marked the first anniversary of the dedication of NASA's Goddard Space Flight Center. During this year, seven Goddard satellites were orbited and the Center successfully operated the new 18-station world tracking network for the first manned orbital flight, began expansion of the 13-station scientific satellite tracking and data network, saw some 70 of its sounding rocket payloads launched from Wallops Island, established the Institute for Space Studies in New York, and added three buildings and 700 persons to its staff. 16

1962 (Cont.)

March—Continued

26 The coordination of international arrangements for exchange and dissemination of weather satellite information was on the agenda of the third session of the U.N.'s Commission for Synoptic Meteorology as it opened a 26-day session in Washington.

27 NASA fired a Nike-Cajun rocket from Wallops Island, which released a sodium vapor cloud between 25 and 74 miles altitude. Rays of the setting sun colored the sodium cloud red (instead of sodium vapor's normal yellow).

28 The Senate Aeronautical and Space Sciences Committee unanimously approved a bill for ownership and operation of the Nation's commercial communications satellites.

29 A four-stage NASA Scout rocket carried the P–21A probe payload 3910 miles into space and 4370 miles downrange from Wallops Island.

During the Month During the month NASA completed work on its first major launching facility on the West Coast, a Thor-Agena pad at Vandenberg Air Force Base, Calif. A used gantry was shipped from Marshall Space Flight Center and installed at a $1 million saving over cost of new construction. This pad would be used for NASA polar-orbit launches, such as for Echo II, Nimbus, and POGO (Polar Orbiting Geophysical Observatory).

April

1 Today marked the beginning of the third year of successful weather satellite operation by Tiros satellites. Tiros I, launched on April 1, 1960, performed beyond all expectations, operated for 78 days, transmitted almost 23,000 cloud photos, of which some 19,000 were useful to meteorologists. Tiros II, launched November 23, 1960, had transmitted more than 33,000 photos and one year after launch was still occasionally taking useful photos. Tiros III, launched July 12, 1961, took 24,000 cloud photos and was most spectacular as a "hurricane hunter." Tiros IV, launched February 8, 1962, had averaged 250 operationally useful photos per day.

2 OSO I, launched March 7, 1962, was reported by NASA to be performing well. As of this date, 360 telemetry data tapes had been recorded from 403 orbits. About 1 year would be required for complete analysis of the data.

11 NASA Administrator James E. Webb, testifying before the Senate Committee on Commerce, supported the President's bill setting up a communications satellite corporation and approved of the Senate amendments, but noted his reservations on the one that would direct the FCC to encourage communications common carriers to build and own their own ground stations.

13 NASA Administrator James E. Webb, addressing the National Conference of the American Society for Public Administration in Detroit, said: "No new department or agency in the recent history of the Executive Branch of the Federal Government was created through the transfer of as many units from other departments and agencies as in the case of NASA. Three and one-half years ago, NASA did not exist. Today NASA comprises approximately 20,500 employees, ten major field centers, and an annual budget approaching the $2 billion mark."

15 The U.S. Weather Bureau began daily international transmissions of cloud maps based on photos taken by Tiros IV.

1962 (Cont.)

April—Continued

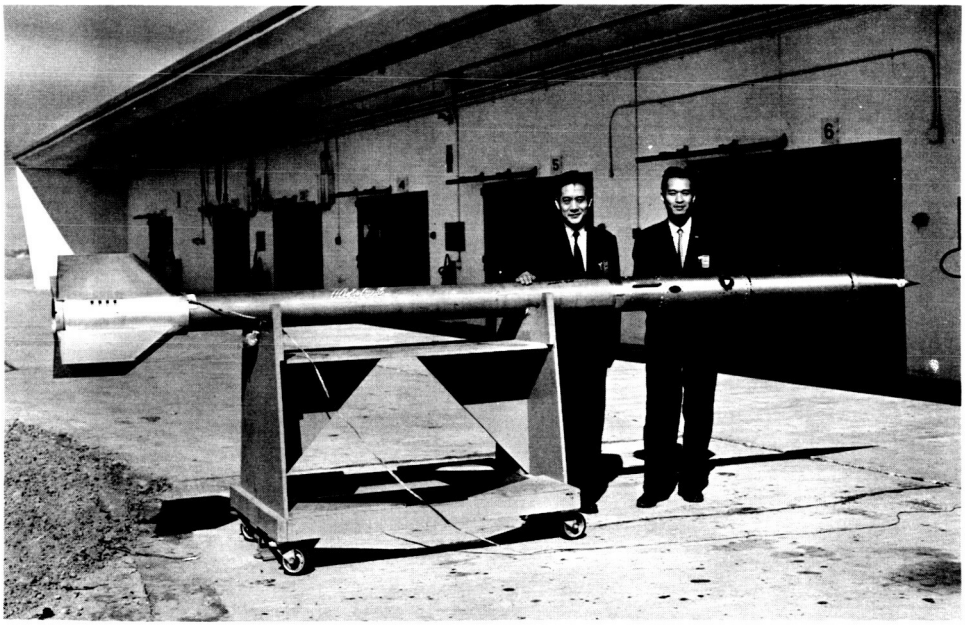
NASA launched a Nike-Cajun sounding rocket from Wallops Island which detonated 12 grenades at altitudes from 25 to 57 miles. 17

The first transmission of TV pictures in space was made via orbiting Echo I. Signals were beamed from MIT's Lincoln Laboratory, Camp Parks, Calif., bounced off Echo I, and received at Millstone Hill near Westford, Mass. 24

Ariel I (1962σ1), the first international satellite, a joint U.K.–U.S. effort was launched into orbit from Cape Canaveral by a Thor-Delta booster. The 136-lb spacecraft was built by GSFC and carried six British experiments to make integrated measurements in the ionosphere. Three experiments measured electron density, temperature, and composition of positive ions in the ionosphere, while two experiments were designed to monitor the intensity of radiation from the sun in the ultraviolet and x-ray bands of the solar corona. The sixth experiment was designed to measure cosmic rays, supported by simultaneous experiments on the ground, on aircraft, and on balloons. 26

Japan and the U.S. launched a joint sounding rocket from Wallops Island. NASA provided the Nike-Cajun rocket, launch facilities, data acquisition, and a Langmuir probe to measure electron temperature. Japan furnished other instrumentation, a device designed to make simultaneous measurements of electron temperature and density, functions which had required two separate instruments. The height of the flight was 75.6 miles.

NASA graduated its first group of Project Mercury tracking personnel from a new course at Wallops Island, the seven graduates being personnel from firms having contracts with DOD and NASA.



Dr. Kunio Hirao and Mr. Toshio Muraoka at the launch of the first U.S.-Japanese space probe.

1962 (Cont.)

April—Continued

28 The second Nike-Cajun probe with a Japanese payload was canceled for the third time because of high winds at Wallops Island.

A spokesman at the British tracking station at Winkfield said that "Ariel I's signals are good and everything seems satisfactory."

During the Month Tiros IV continued in operation and, to a great extent, was providing excellent data. Over 20,000 pictures had been received. A total of 217 nephanalyses had been prepared up to March 26, and 199 had been transmitted over national and international weather circuits.

Tiros II was turned on late in April by an unknown spurious source. An engineering investigation was run in early May before turning it off again. An analysis of the data indicated that some usable IR data were obtained.

May

2 NASA scientists reported to the COSPAR session that data from Explorer IX indicated that the upper atmosphere was heated by sunspot activity.

3 Two GSFC scientific sounding rockets were launched from Wallops Island. An Iris research rocket launched with test instrumentation did not achieve its programmed altitude and landed 175 statute miles downrange.

The House of Representatives passed the Communications Satellite Act of 1962 by a vote of 354 to 9, creating machinery to operate the U.S. portion of a worldwide communications satellite system.

12 OSO I had completed 1000 orbits; approximately 900 telemetry data tapes had been acquired and forwarded to all experimenters.

16 to 17 The second and third joint Japan-U.S. space probes were successfully launched from Wallops Island; the second Nike-Cajun reached a 76-mile altitude and the third, and last—a night shot—reached an 80-mile altitude.

17 The first of a series of 80 rocket probes to determine wind patterns over Cape Canaveral was initiated with the launch of a single-stage Nike to 80,000 ft, where it released a white smoke screen for photographic study.

18 The Geophysics Corp. of America reported receipt of a Weather Bureau contract to study and explain the formation of vast bands of cloud patterns in the upper atmosphere, a phenomena first revealed in photographs relayed by Tiros I.

20 Building 5 at GSFC was completed.

21 The Senate Commerce Committee tentatively approved a space communications satellite corporation bill after adopting 32 amendments, one virtually identical to the bill passed by the House on May 3.

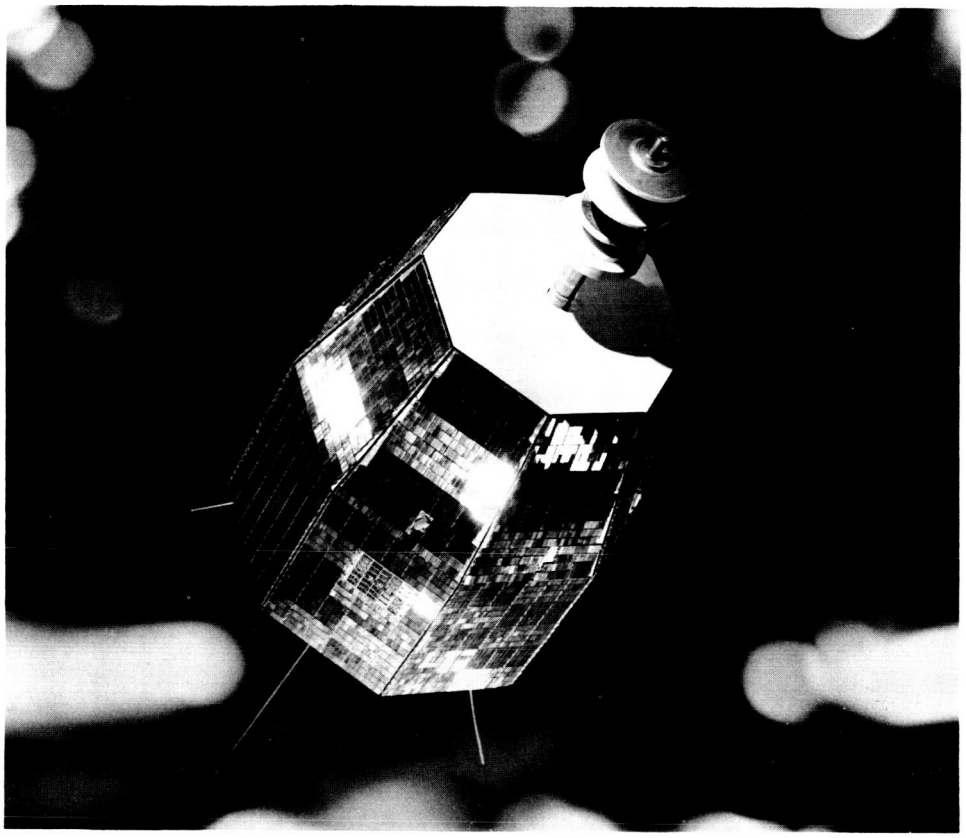
29 NASA announced that Ariel I, the U.K.–U.S. ionosphere satellite launched on April 26, was functioning well except for one experiment, the solar ultraviolet detector.

During the Month Checkout was completed for the Alaska Data Acquisition Facility near Fairbanks, and the University of Alaska assumed responsibility. Part of the GSFC system, the Alaskan facility is an 85-ft dish; and its associated electronics system will be used on tracking and data acquisition of the polar-orbiting Nimbus, EGO (Eccentric Geophysical Observatory), and POGO (Polar-Orbiting Geophysical Observatory) satellites.

1962 (Cont.)

June

A cooperative program for testing the Relay and Telstar communications satellites by NASA and communications organizations in the U.S., Europe, and South America was announced by NASA. Ground stations and the communications experiments would be provided by AT&T, IT&T, the British General Post Office, the French National Center for Telecommunications Studies, the West German Post Office, the Brazilian Department of Posts and Telegraphs, and the Telespazio of Italy. 5



Relay I, launched December 13, 1962.

Three sounding rockets were launched from Wallops Island. The first, a Nike-Apache, launched at 7:40 p.m. (EDT) with a 70-lb payload containing a pitot-static probe, reached a 78-mile altitude. The second, a Nike-Cajun, launched at 8:05 p.m., consisted of 11 explosive charges and a balloon, released between 25 and 64 miles altitude. The third, a Nike-Asp, was launched at 8:56 p.m. and consisted of sodium vapor clouds to measure atmospheric winds and diffusion, ejected at about 20 miles and extending to a peak altitude of about 100 miles. 6

A Nike-Cajun vehicle with an experiment to measure winds and temperatures in the upper atmosphere was launched from Wallops Island. In the night flight, 12 special explosive charges were ejected and detonated at intervals from about 25 up to 58 statute miles altitude. 7

1962 (Cont.)

June—Continued

7 NASA announced selection of Bendix Corp.'s Radio Division, Towson, Md., for a contract to operate five of NASA's worldwide Project Mercury tracking and communications stations.

14 Tiros IV was no longer transmitting pictures usable for global weather forecasting, although it was still taking "direct" pictures on command which were suitable for limited U.S. weather analysis.

14 (to Sept. 15) The GSFC Test and Evaluation Division conducted a "simulation" summer workshop to promote the exchange of technical information between GSFC and the rest of the scientific community.

15 A two-stage Nike-Apache sounding rocket was launched from Wallops Island with a 95-lb payload to a 89-mile altitude with a GSFC experiment to measure electron density and electron collision frequency in the ionosphere under undisturbed conditions.

NASA launched the first two of six tests on the performance of the Canadian Black Brant sounding rocket. The first carried a payload to 58 miles above Wallops Island, the second reached 62 miles.

The U.S. Weather Bureau announced that the formation of the season's first hurricane would be detected by one or all of its battery of ships, planes, radar systems, and Tiros weather satellites. Last year Tiros III had discovered Hurricane Esther as it was forming in the Atlantic Ocean. Altogether, the Weather Bureau said, Tiros III had seen five hurricanes and one tropical storm in the Atlantic, two hurricanes and a tropical storm in the eastern Pacific, and nine typhoons in the central and western Pacific. In preparation for the 1962 season, the Weather Bureau arranged to transmit satellite cloud photographs by photofacsimile to warning centers in San Juan, New Orleans, and Miami, where they would be used in forecasting and tracking tropical storms.

18 NASA selected the Hughes Aircraft Co. for negotiating a $2.5 million, 6-months study contract on an Advanced Syncom (synchonous communications) satellite. The contract covered satellite subsystems which would require long lead-time developmental and feasibility work. This second-generation Syncom would be a 500-lb, spin-stabilized satellite capable of relaying hundreds of telephone calls or carrying several TV channels. (The first-generation Syncom, for which Hughes was prime contractor, was limited to single telephone channel relay.) The Syncom project is under the technical direction of GSFC.

OSO I, launched March 7, 1962, had provided 1000 hours of data from its solar-pointed experiments prior to failure of its real-time telemetry on May 22, 1962.

19 Tiros V (1962A-α1) was launched into orbit by a Thor-Delta booster from Cape Canaveral. A faulty guidance system placed it into an elliptical orbit (apogee, 604 miles, perigee, 367 miles, period, 100.5 min.) instead of a 400-mile circular orbit.

The Nile delta as seen from a Tiros satellite.

1962 (Cont.)

June—Continued

An Aerobee 150A was launched from Wallops Island with a 271-lb payload boosted to 97-mile altitude; it carried a camera to study the behavior of liquid hydrogen under conditions of symmetrical heating and zero gravity. 20

OSO I began transmitting real-time data on solar observation after 5 weeks of intermittent transmittal. 24

July

OSO I was transmitting continuous signals, and 20 percent of real-time data was being acquired from each 95-min orbit. 1

Ariel I discovery of a new ion belt, at an altitude of 450 to 500 miles, was announced at the International Conference on the Ionosphere, London, by Prof. James Sayers of Birmingham University. 3

Tiros V stopped transmitting pictures from the Tegea-lens, medium-angle camera. The Tegea camera system transmitted 4701 pictures of which 70 percent were considered of excellent quality. The wide-angle Elgeet-lens camera, which was still functioning, had transmitted 5100 pictures to date, some of which aided in the analysis of Typhoon Joan over the western Pacific. 9

Telstar I (1962A–ϵ1), the first privately financed satellite, was launched into orbit from AMR by a Delta booster. Its apogee was 3503 miles, perigee 593 miles, inclination 44.79 degrees, and period 157.8 min. The satellite was funded by the American Telephone and Telegraph Co. (AT&T) under a NASA–AT&T agreement of July 27, 1961. 10

July 10th marked the first commercial transmission of live TV via satellite and the first transatlantic TV transmission, when Telstar I demonstrated its

1962 (Cont.)

July—Continued

vast capabilities. In one test pictures were telecast from Andover, Maine, to Telstar I, then returned and placed on all three major TV networks in the U.S.

The launching of Telstar I marked the tenth consecutive successful flight of the three-stage Delta rocket. The history of Delta goes back to the Thor–Able and the earlier Vanguard, from which it acquired its upper stages.

A picture transmitted by Telstar.

11 A NASA invention award was made to David H. Schaefer of GSFC, along with 13 members of the Lewis Research Center staff.

13 A transatlantic telephone conversation via Telstar I was held between Jacques Marette, French Communications Minister, and AT&T President Eugene McNeely. On the next orbit, Sir Ronald German, Director-General of the British Post Office, spoke with McNeely. Technicians had unofficially talked on this transatlantic circuit the day before, July 12.

14 Cleveland educators pointed out that the transatlantic communications prompted by Telstar I and other satellites would be a tremendous incentive to foreign language study.

16 Britain transmitted the first transatlantic color TV, twice transmitting still photographs to Andover.

18 NASA launched a rigidized Echo-type balloon on a Thor booster to 922 miles in an inflation test. Nicknamed "Big Shot," the 13-story balloon was inflated successfully and was visible for 10 minutes from Cape Canaveral. A movie film capsule parachuted into the sea northeast of San Salvador was recovered by three "pararescue" men of the Air Rescue Service. This was the largest man-made object sent into space, the previous record being held by the 100-ft Echo I.

1962 (Cont.)

July—Continued

The Weather Bureau transmitted Tiros V photographs to Australia from Suitland, Md., the first time Tiros photographs had been transmitted abroad for current weather analysis by a foreign country. The photographs were of cloud formations west of Australia. 20

Telstar I relayed two 20-minute live TV shows, the first formal exchange of programs across the Atlantic via Telstar I. 23

The United States Information Agency reported that the USSR had been invited to participate in the Telstar I broadcasts but had never answered the invitation.

Three major TV networks in the U.S. telecast separate 5-minute newscasts via Telstar I, each featuring their respective Paris news correspondents. 24

GSFC awarded a contract to IBM Corporation's Federal Systems Division for computer support services of Mercury flights, nonrendezvous Gemini flights (orbital flights of two men in one capsule), and the unmanned lunar flights scheduled as part of Project Apollo. 27

Former President Dwight D. Eisenhower spoke on the people-to-people benefits to be gained by live international communications in a broadcast televised to the U.S. via Telstar I from Stockholm, Sweden. 31

August

The Advanced Syncom satellite, being developed for NASA by the Hughes Aircraft Co., probably would carry four radio signal repeaters and would provide up to 300 two-way telephone channels or one TV channel. 3

General Electric announced that the control system for the first Orbiting Astronomical Observatory (OAO) had successfully completed its first simulated space flight test. 7

NASA launched an Aerobee 150A sounding rocket from Wallops Island. Its 256-lb payload rose to 92-mile altitude and traveled a 60-mile distance downrange. 8

Speaking on the Senate floor, Senator Estes Kefauver reiterated his belief that the communications satellite bill (H.R. 11040) "proposed the most gigantic giveaway in the history of this country. . ." 9

This marked the second birthday of Echo I, the passive communication "balloon" satellite. Since launch the Mylar balloon had orbited the earth 9000 times and traveled 277,257,678 miles; it had been used for approximately 150 communication experiments. 12

Five NASA scientists, led by Ozro M. Covington of GSFC, arrived in Australia to inspect proposed sites for new tracking stations.

The USSR declined the offer of U.S. networks to use the Telstar I satellite for relaying live telecasts of orbiting Soviet cosmonauts. 13

NASA announced that GSFC had awarded three 3-month study contracts on the design of an Advanced OSO, to be launched into polar orbit during 1965. The Advanced OSO would aid development of a method of predicting flares. 15

Construction began on Building 11, the Applied Sciences Laboratory at GSFC. 16

1962 (Cont.)

August—Continued

19 Nasa launched a Scout vehicle from Wallops Island in an experiment to make direct measurements of radiative heating during atmospheric entry.

22 The French government announced its first satellite, weighing 150 lb, would be launched in March 1966 and would be followed by others three and four times as large.

23 A Nike-Apache launch vehicle carried a 63-lb payload to approximately 80 miles above Wallops Island, in an experiment to measure ion concentration and composition in the upper atmosphere.

The International Edition of the New York Times contained articles (about 5000 words) transmitted from New York to Paris via Telstar I.

27 DOD announced that Telstar I was being used to synchronize master clocks in England and the U.S. An accuracy of 10 millionths of a second was obtained in the first demonstration when stations at Andover, Maine, and Goonhilly Downs, England, simultaneously sent time-check signals via Telstar I on August 25.

GSFC announced it was training Italian scientists and engineers for the launching of Italy's first satellite. The 165-lb satellite would be launched by 1965 from a platform in the Indian Ocean off the eastern coast of Africa.

31 NASA launched a four-stage Scout from Wallops Island with a reentry heatshield experiment. Two stages carried the payload to nearly 80 miles altitude, while the other two stages fired the payload back to earth at speeds near 18,000 mph.

September

5 An agreement establishing the Italy–U.S. cooperative space program, signed in May, was confirmed in Rome by Italian Foreign Minister Attilio Piccioni and U.S. Vice President Lyndon B. Johnson. The Memorandum of Understanding between the Italian Space Commission and NASA provided a three-phase program, expected to culminate in the launching of a scientific satellite into equatorial orbit. Generally, NASA would provide Scout rockets and personnel training; Italians would launch the vehicle with its Italian payload and would be responsible for data acquisition as well as for a towable launch platform located in equatorial waters.

6 IT&T announced plans for the NASA Project Relay satellite communication experiment to link North and South America.

15 Signals from Ariel I had been received during the past week by tracking stations. Ariel I had stopped transmitting after a U.S. high-altitude nuclear test because of radiation damage to the satellite's solar cells. Although resumed transmission was not continuous, it did demonstrate Ariel's regained capability to return scientific data from space.

NASA announced that the sixth Tiros weather satellite would be launched into orbit from Cape Canaveral on September 18, at the earliest. The launch date was moved 2 months ahead to provide backup for Tiros V cloud-cover photography during the last half of current hurricane season and to provide weather forecasting support for Astronaut Walter M. Schirra's orbital space flight September 28. The wide-angle TV camera in Tiros V continued to operate, but its medium-angle Tegea lens had stopped functioning on July 2 because of "random electrical failure in the camera's system."

1962 (Cont.)

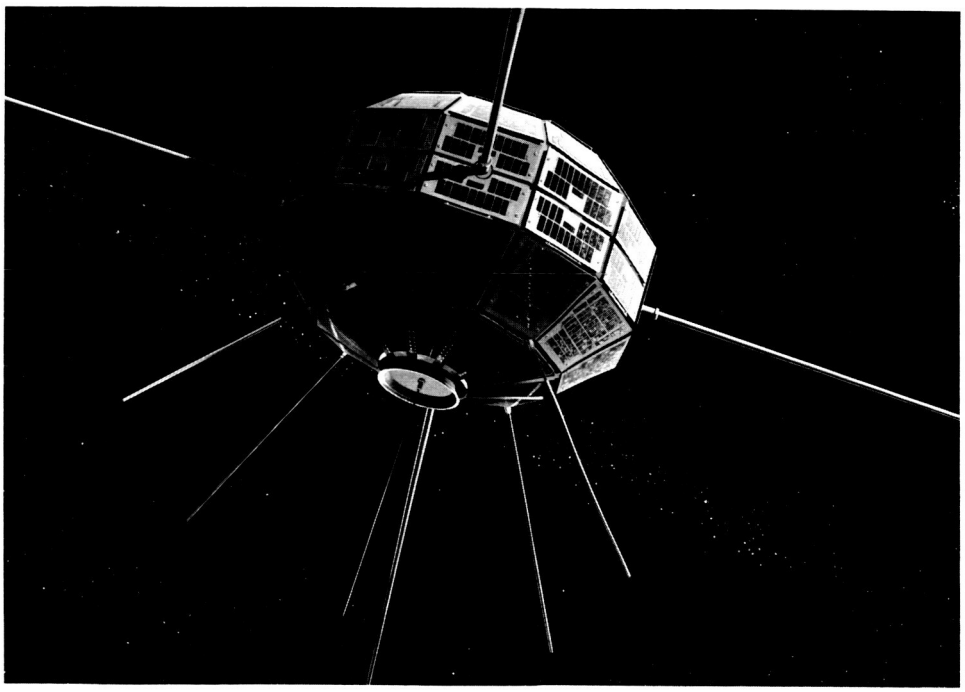
September—Continued

Tiros VI (1962A–Ψ1) was placed in orbit by the three-stage Delta vehicle from Cape Canaveral at 4:45 p.m. EDT (apogee, 442 miles; perigee, 425 miles; period, 98.7 min; inclination, between 58.3° N and S latitude). 18

An Aerobee 150A was launched from Wallops Island, the rocket reaching a 117-mile altitude in an experiment to measure the absolute intensity of the spectrum of stars with 50A resolution and to measure ultraviolet fluxes. 22

NASA announced plans to launch two Project Echo balloons during October. To be filled with helium while on the ground near the White Sands Missile Range, N.M., one balloon would be like Echo I, measuring 100 ft in diameter and the other would be Advanced Echo type measuring 135 ft in diameter. 28

Alouette (1962B–α1), the Swept Frequency Topside Sounder, was placed in polar orbit by a Thor-Agena B from Vandenberg Air Force Base. It was a Canadian Defence Research Board project, the first spacecraft built by any country other than the U.S. and USSR. 29



Alouette, launched September 29, 1962.

NASA launched an Aerobee sounding rocket from Wallops Island. The 259-lb instrumented payload reached a 106-mile altitude in a test to map sources of photons in specific wavelengths in the nighttime sky. 30

October

Explorer XIV (1962B–γ1), the Energetic Particles Satellite, was launched. It studied trapped corpuscular radiation, solar particles, cosmic radiation, and the solar winds. 2

1962 (Cont.)

October—Continued

16 A Nike-Apache two-stage sounding rocket carried a 65-lb instrumented payload to 103 miles above Wallops Island.

20 An Echo I type balloon launched from the White Sands Missile Range ruptured at a 21-mile altitude and fell back to earth 91 min after launch. The 100-ft-diameter balloon was to have reached 24 miles in structural test.

21 NASA announced that Swedish and U.S. experimenters were studying samplings of noctilucent clouds obtained in four Nike-Cajun sounding rocket flights during August. Preliminary analysis indicated that samples taken when noctilucent clouds were observed contained significantly more particles than when no noctilucent clouds were visible. Analysis of the origin and structure of the particles might take up to a year. Participants in the project would include scientists from the University of Stockholm Institute of Meteorology, Kiruna (Sweden) Geophysical Observatory, GSFC, and USAF Cambridge Research Center.

22 Construction was begun on Building 12, the Tracking and Telemetery Laboratory at GSFC.

27 Explorer XV (1962B–λ1) was placed in orbit by a Thor–Delta vehicle launched from Cape Canaveral. The initial orbital data: apogee, 10,950 miles; perigee, 195 miles; period, 315.3 min; inclination, 18.02 degrees to the equator; velocity at apogee, 6015 mph; and velocity at perigee, 21,598 mph.

29 An Aerobee sounding rocket launched from Wallops Island carried a 230-lb payload to 116 miles. It landed in the Atlantic Ocean 59 miles from the launch site.

NASA officials said that five experiments aboard Explorer XV were working well but that two others had been adversely affected by the satellite's excessive spin rate.

30 NASA announced that 19 experiments would be included on POGO (Polar Orbiting Geophysical Observatory), to be orbited by a Thor-Agena vehicle launched from PMR. POGO would be the second in the OGO (Orbiting Geophysical Observatory) series and the first OGO in a polar orbit; it was scheduled for launch in early 1964.

31 Explorer XIV had transmitted 589 hours of data to GSFC, which had released about 240 hours of data to the various experimenters.

November

1 NASA reported that the radiation satellite, Explorer XV was spinning at the rate of 73 rpm instead of a desired 10 rpm because of failure of the despin weights to deploy. Preliminary data indicated most experiments were functioning and that data received were of good quality.

5 GSFC announced the award of $12 million worth of contracts for tracking-network modification in preparation for lengthy manned space flights.

7 NASA fired two experimental rockets into the upper atmosphere within ½ hour of each other, to obtain a comparison of electron density and wind profiles measured at about the same time.

1962 (Cont.)

November—Continued

GSFC announced it would conduct experiments using a Laser in tracking the S–66 ionosphere beacon satellite, to be launched into a polar orbit early next year. 8

NASA Project Officer reported that Canadian Alouette, topside-sounder satellite, was performing as expected. Launched Sept. 28, it was considered "a very successful experiment since it is producing not only ionospheric data but also information about the earth's magnetic field . . . Operation of the satellite continues to be normal . . ." 9

The Hughes Aircraft Co. reported the final assembly of the Syncom satellite had been completed. The spacecraft was undergoing final checkout before delivery to Cape Canaveral, where it would be launched in early 1963.

It was reported that TAVE (Thor–Agena Vibration Experiment), flown with the Thor-Agena launching Alouette, measured low-frequency vibrations to the Agena stage, and measured spacecraft interfaces during the Thor boost phase. 12

In a news conference at MIT, Dr. James A. Van Allen predicted the radiation caused by the U.S. atmospheric nuclear test in July should be "undetectable" by July 1963. Dr. Van Allen reported that signals from Injun, Telstar I, Explorers XIV and XV showed that the electronic stream had disappeared within a few days of the U.S. explosion and that the electrons at a 600-mile altitude were now undetectable. Electrons at a 900-mile altitude were still creating radio-astronomy interference, he acknowledged, but this should be gone by next July. 14

A Nike-Cajun sounding rocket was launched from Fort Churchill, Canada, under direction of GSFC. The second stage failed to ignite, so that the rocket reached an altitude of only about 9.5 miles. 16

An Aerobee sounding rocket was launched from Wallops Island. The vehicle carried a 211-lb instrumented payload up to 128 miles in an experiment to study the behavior of liquid hydrogen exposed to radiant heating and zero gravity. 17

A Spaerobee sounding rocket was launched from Wallops Island with a 90-lb payload to measure electron and neutral particle temperatures at 75- to 225-mile altitudes. 20

Bell Telephone Laboratories reported the failure of Telstar I to respond to transmitter cutoff commands, followed by the satellite's turning off its command receiver. Bell scientists expected to correct the Telstar I communications system by remote control. 26

Franco–American scientific sounding rocket launchings were coordinated when two U.S. launchings were made from Wallops Island while France launched one from Algeria (and failed to launch one from France). The first U.S. rocket (a Nike-Cajun), fired at 5:57 a.m., carried a Langmuir probe to determine electron density and the temperature of the E layer of the ionosphere (50 to 100 mile altitude); the second (Nike-Apache), launched at 6:15 a.m., released a sodium vapor cloud to a 106-mile altitude, which spread over 100 miles of the Eastern seaboard. 30

Sounding rocket fired from Fort Churchill.

1962 (Cont.)

December

Three sounding rockets were launched from Wallops Island in a series of GSFC experiments to study the structure and composition of the upper atmosphere and ionosphere:

A Nike-Apache carried a 65-lb payload to a 105-mile altitude; the payload was designed to measure electron density, temperature, ion density, and conductivity of the ionosphere.

A Nike-Apache with a 70-lb payload containing a pitot-static probe reached 82 miles. It carried instrumentation designed to measure pressure, temperature, density, and winds in upper atmosphere.

A Nike-Cajun was fired with a payload to measure winds and temperature in the upper atmosphere, the payload consisting of 12 special explosive charges which were detonated at intervals from about 24 to 58 miles.

A Nike-Apache was also launched from Eglin Gulf Test Range, Fla., to a 128-mile altitude to measure winds by the sodium vapor method.

1962 (Cont.)

December—Continued

Also on December 1st, the medium angle camera on Tiros VI stopped transmitting pictures during orbit 1074, but the wide-angle camera was still sending pictures of "excellent quality."

GSFC launched two Nike-Cajun sounding rockets, one from Wallops Island, and one from Fort Churchill, Canada, for the purpose of comparing data on winds and temperatures in the upper atmosphere. 4

A Nike-Cajun launched from Wallops Island carried electron-density and temperature instrumentation to an 80-mile altitude, as part of the current series of upper-atmosphere studies. 5

A sodium-vapor experiment launched with a Nike-Apache vehicle from Wallops Island was not successful because the payload did not perform properly.

A Nike-Cajun sounding rocket launched from Wallops Island to measure high-altitude winds and temperatures carried a payload consisting of 12 special explosive charges which were ejected and detonated at intervals from 24- to 57-miles up. 6

Incorporators of the Communications Satellite Corp., authorized by the Communications Satellite Act of 1962, decided that temporary headquarters for the new company would be established in Washington, D.C. 10

Relay I (1962 B–υ1) was launched. Its purpose was to investigate wide-band communications between ground stations at a low altitude. 13

The power supply on Relay I remained too low to operate the satellite's instrumentation properly. 15

Explorer XVI (1962B–χ1) was launched into orbit by a four-stage Scout vehicle from Wallops Island (initial orbital data: apogee, 733 miles; perigee, 466 miles; period, 104 min; inclination, 52 degrees to the equator) and it began measuring micrometeoroids in space. 16

The Relay I 136-Mc beacon was detected by tracking stations at Santiago, Johannesburg, and Woomera, indicating the beacon had spontaneously turned itself on.

Although the Relay I power supply remained low, the Nutley, N.J., ground station was able to obtain about 10 minutes of usable telemetry data. 17

Spontaneous transmission of the Relay I 136-Mc beacon signal had been observed at Minitrack stations, NASA Relay Project Officer J. Russell Burke reported. 18

The U.S. Weather Bureau announced the development of an infrared spectrometer, to be flight-tested in new balloons during the next 6 months. The 100 lb "flying thermometer" was planned for use in Nimbus weather satellites. 19

Management of Project Anna, a geodetic satellite program, was transferred from DOD to NASA. Anna I–B (1962B–μ1), launched October 31, would remain a responsibility of DOD, with NASA scientific direction, but further launchings would be planned and executed by NASA. 20

Eugene W. Wasielewski, Associate Director of GSFC, told the National Rocket Club that Ariel I (U.K.–U.S. satellite) was "beginning to show signs of trouble."

1962 (Cont.)

December—Continued

21 Canada and the U.S. announced a cooperative venture to build a data acquisition station for the Nimbus meteorological satellite program at Ingomish, Nova Scotia.

27 GSFC officials reported that they had received "indications the voltage had recovered somewhat" in Relay I, but they doubted that its communications mission would be accomplished.

28 Interaction of winds in the lower atmosphere and turbulence in the upper atmosphere were discussed at the meeting of the American Association for the Advancement of Science by University of Chicago scientist Colin O. Hines.

30 AT&T announced that Telstar II communications satellite would be launched in the spring of 1963; it would attempt to avoid or overcome radiation damage which had shortened the life of Telstar I.

31 Goddard Space Flight Center had over 2850 people employed or committed for employment.

During the Month Modulation from Ariel I appeared on the carrier approximately 10 days out of the 31. Data received indicated that the x-ray experiment had failed.

Appendix C

SCIENTIFIC EXPLORATION OF SPACE*

by
Dr. Harry J. Goett
Director, Goddard Space Flight Center

I have found it a very rewarding experience to prepare this talk that I am to give tonight for two reasons. In the first place, the task of putting it together required some standing back from the day-to-day activities of a busy program in order to do some "stock-taking" on its accomplishments during the past several years. This is a good thing to do occasionally, and I hope you are as impressed with the results as I am.

Secondly, my story tonight is a relatively untold one. With the notable and satisfying exception of the recent flight of John Glenn, the main story of space projects to date seems to have been the advance preparation for the launch and the launch itself. After the headline "Satellite in Orbit," the story seems to end. Actually, the project has just reached the threshold of its useful life. To end the story here is equivalent to ending the biography of a great man on the day of his graduation from school.

It is appropriate that the part of the story I am to tell should start with Vanguard I (Figure 1).

I am sure that all of you are familiar with its pre-launch trials and tribulations, and probably contributed your share of "body English" to get it in orbit. But how many realize that this satellite not only is still up there but that it is also still supplying useful scientific data, almost four years after it was launched? A tiny radio transmitter, powered by six solar cells which still put out about $\frac{1}{10}$ of a milliwatt when in sunlight, is operating and enabling us to continue to track Vanguard I accurately. (Since Vanguard I went into orbit it has traveled more than 541,600,000 miles.)

We have observed Vanguard I for nearly four years. In Figure 2 you see our observations in terms of perigee height versus time. This may appear to be just the normal scatter in data around a mean curve due to lack of accuracy in the measurements. However, by detailed analysis these variations in the orbit have been correlated with various physical causes—radiation pressure of the sun, the shape of the earth, and fluctuations in density of the upper atmosphere—to name the three main per-

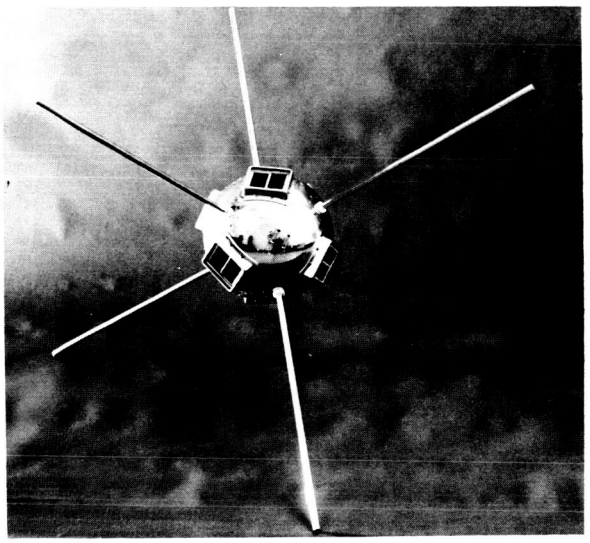


FIGURE 1.—Vanguard I.

*Presented before the Franklin Institute, Philadelphia, Pennsylvania, March 8, 1962.

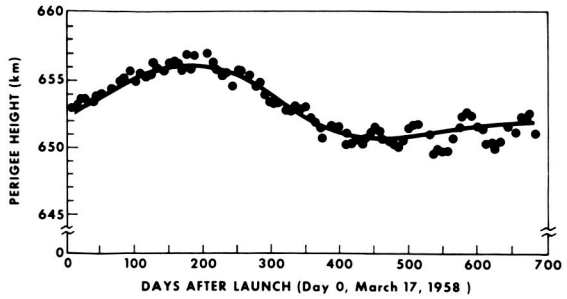


FIGURE 2.—Vanguard orbit variation.

turbations. The major long-term variation is due to the sun's radiation pressure. It also may be of interest to look at the details of the variation which led us to conclude that the earth is pear-shaped.

From the data in Figure 2, we have extracted a periodic orbital variation shown in Figure 3.

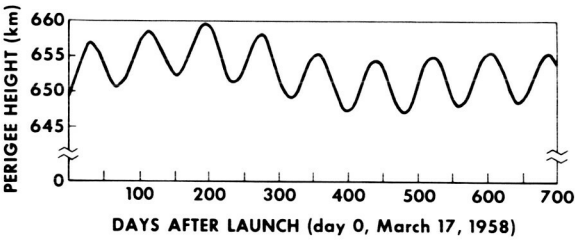


FIGURE 3.—Third harmonic variation of Vanguard I.

It can be shown that this variation is due to a third harmonic in the earth gravitational pull which can be accounted for by a distortion of the earth such as shown in Figure 4. (Note the deviations from the sphere at certain points.) There is also a second harmonic in the data

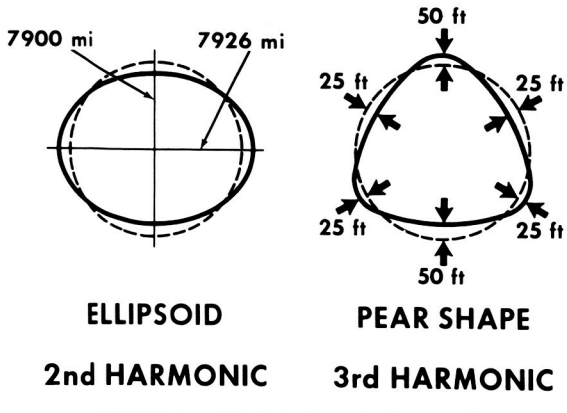


FIGURE 4.—Harmonics of the earth.

which gives an accurate measure of the flattening or oblateness of the earth, shown in this figure.

You may ask why much importance is attached to a 50-foot variation in a radius of 4000 miles or to the precise measure of the oblateness. It is of considerable interest to geologists and geodesists studying the earth's formation. For instance, from these shape variations we can deduce certain characteristics of the earth's mantle, including its bending strength and resistance to known distorting forces. One interesting inference has been drawn that this shape was set some 50 million years ago when the day was 23 hours 30 minutes in length.

Echo I (Figure 5) has given useful information of the same type. This satellite was launched in order to conduct communications

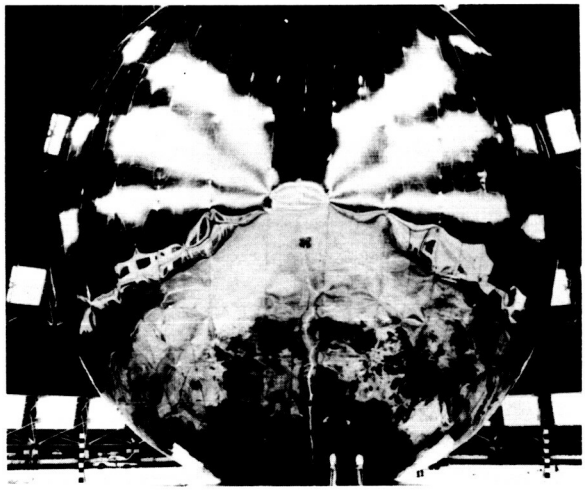


FIGURE 5.—Echo I.

experiments; radio transmissions were bounced off it and spanned the country and ocean. However, the very large size of the inflated Echo I balloon, in proportion to its weight, enabled it to serve another useful purpose. It proved most responsive to small changes in resistance in orbit. Its orbital variations have therefore served as a very sensitive measure of the density variations it encounters. A most interesting example of this is illustrated in Figure 6. Shown in this figure are the orbital period variations versus time. You will note at one point a marked change in the period, which implies a change in resistance. This change occurred at

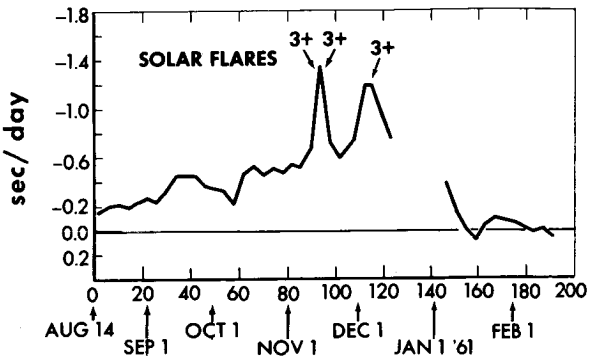


FIGURE 6.—Variation period of Echo I.

the same time that a Class 3 solar flare was observed from the earth. It was possible to deduce that this flare, in a manner I will describe in more detail later, heated up the upper atmosphere and caused it to expand, and increased in density at the altitudes of the Echo I orbit.

Extensive correlation with period variation of Echo I and other satellites has led to the conclusion of a marked coupling between the 11-year solar sunspot cycle and the temperature of the upper atmosphere. Figure 7 shows the correlation over the past four years during which there have been satellites in orbit. An extrapolation into the future is also shown. Needless to say, this anticipated correlation will be watched for years to come.

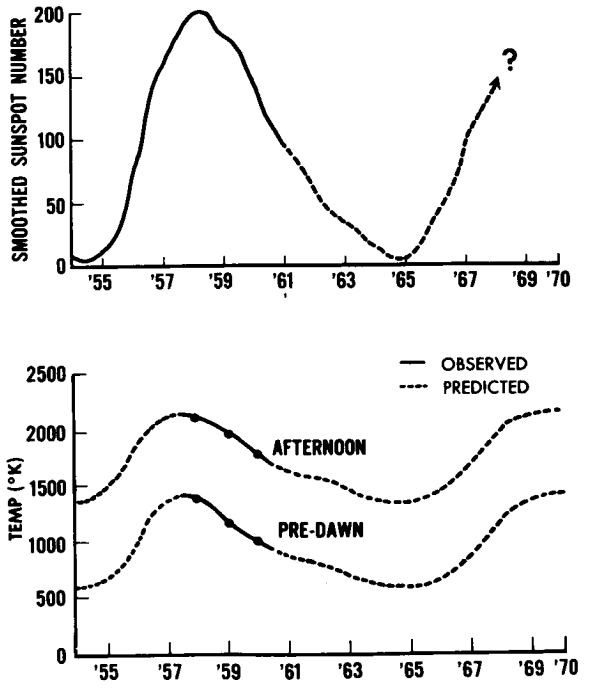


FIGURE 7.—Upper atmosphere temperature variations during sunspot cycle.

Thus far, I have been talking about the "first generation" of satellites. They are characterized by an absolute minimum of instrumentation. Their scientific value has primarily been derived by observing their orbital variations from the ground. I would like now to shift to the "direct measurement" satellites, which carry instruments on board to sample and measure the characteristics of the environment in which they find themselves. Explorer I was of this type, and the Geiger tube it carried gave first direct evidence of the Van Allen belts. Later satellites carried instruments of considerably increased complexity.

Contemplate for a second the problem this poses. In many cases these instruments are of the type which heretofore have only been used to conduct precise experiments in an air conditioned lab, isolated from shocks of passing trucks and trains, and with an experienced experimenter constantly adjusting and making his own readings. Now we must take these instruments and operate them at great distances, under the most exacting conditions, in extreme environments. Further, the phenomenon being observed cannot be turned on or off, as can be done in the lab to observe the effect. Before these instruments go into orbit they will be placed on top of a rocket and exposed to shock and vibration conditions much worse than rolling them down the stairs!

Let's take a look at what we want to observe from these direct measurements satellites. The main objectives of our scientific exploration of space are:

Sun-earth relationships
Origin and evolution of the solar system, planets, and moon
Structure of stars and galaxies

The objective "Sun-earth relationships" is the one which concerns most of the satellites that have been launched to date—and it is my primary topic for the rest of this talk. The second item—"Origin and evolution of the solar system, planets, and moon"—has not yet really started; we are still struggling with the tech-

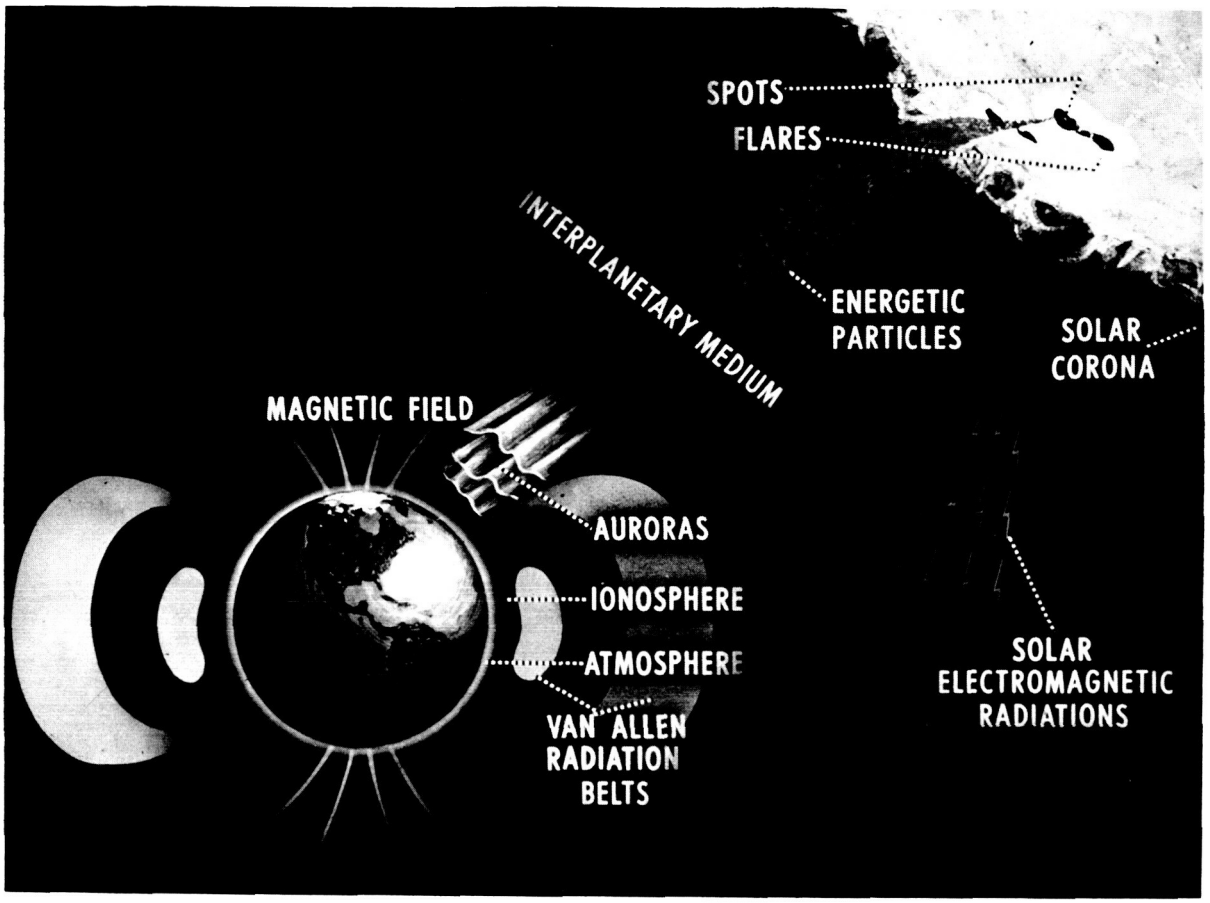


FIGURE 8.—Sun and earth phenomena.

nological problems involved. We have scratched the surface of the satellite observations pertinent to structure of stars and galaxies with some intriguing results, but time will not permit me to touch on these tonight.

The area of sun-earth relationships promises to be one of the most exciting and fruitful areas of research. The results previously quoted from Vanguard and Echo hint at the interrelation that exists between the sun and what goes on in the earth's upper atmosphere. Figure 8 indicates the phenomena of interest; these can conveniently be divided into three general areas.

The first concerns the sun itself. On the sun we will find the causes of the other phenomena of interest—yet, up to the advent of the satellite it has been necessary to study these causes as if through a translucent blindfold, because the earth's atmosphere cuts out a high percentage of the sun's radiation which tells us what is going on up there. Thus, one objective of our sun-earth study is to observe details of sunspots and solar flares from above the earth's atmosphere. The Orbiting Solar Observatory (OSO) has this as its objective. I will discuss more of this shortly.

The second region of interest is referred to as interplanetary space. It is to be distinguished from the near-earth region in that the phenomena in the interplanetary region are dominated by the sun, and relatively uninfluenced by the earth. In this interplanetary region it will be possible to observe solar electromagnetic radiations and particle emissions, essentially uninfluenced by the earth's magnetic field.

The third region is the near-earth region, called the magnetosphere. This is a region in

which, as Figure 8 attempts to portray, the magnetic field of the earth exerts a major influence. The magnetic field lines of the earth interact with the electromagnetic radiations from the sun and divert the flow of energetic particles from the sun. Fortunately, this magnetosphere acts as a protective shield and prevents a major portion of these radiations from impinging on the earth. At the equator, this magnetosphere or shield extends up some 6 earth radii—24,000 miles; at the magnetic poles the shield is much thinner, and solar effects as the aurora occur at much lower altitudes.

If I were to tell this story by proceeding from that which we know most about to that which we know least, it would go from this near-earth region to interplanetary space, to the sun—since our knowledge varies in direct relation to the accessibility of these regions. On the other hand, the story makes better sense by going from cause to effect, that is, to start with the sun.

The satellite from which we will study the sun is the OSO. It stands poised on the launch pad at Cape Canaveral now (or was just launched several hours ago), so obviously I have no results to report. This satellite will be placed in a near-circular orbit about 300 nautical miles above the earth. Figure 9 shows the manner in which it will operate. It is probably the most complicated scientific satellite we have launched to date. One of its prime features is its ability to keep itself pointed at the sun rather than to maintain a fixed orientation in space, by spin stabilization, as most of our other satellites have done. The spacecraft is a gyroscope; there is the wheel of the gyroscope, which will be kept spinning at about 30 rpm, and the fixed or shaft portion. This fixed portion will be pointed at the sun; this is done through the small jets which precess the gyroscope in accordance with mounted sun-sensing instruments. Thus, the sun either remains in constant observation by the instruments mounted in the fixed position or is scanned by instruments looking out from the wheel.

The radiation spectrum over which we will look at the sun is shown in Figure 10. First,

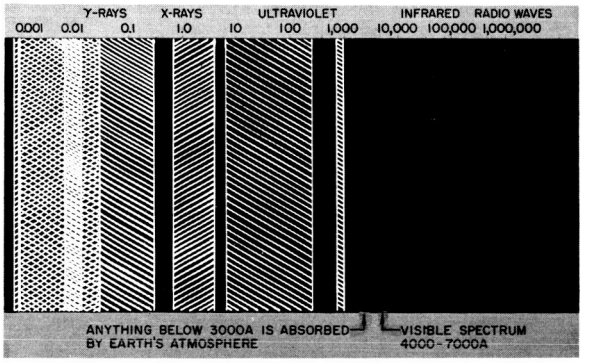


FIGURE 10.—Spectra of radiations with ranges covered by various OSO I experiments.

I call your attention to the fact that from the earth we primarily observe the sun in this relatively narrow visible light band. There, of course, have been observations in this radio frequency range by radio telescopes. OSO is specially suited to the frequencies shown in Figure 10 and carries some thirteen different instruments. Each will observe its selected radiation band. Let's hope it works!

The next region of study is one from which we have some results. As Figure 11 shows, three satellites have been launched into this interplanetary area. Their trajectories are schematically indicated. You recall Pioneer V, which continued transmitting until it was about 20,000,000 miles from the earth. Explorer X went out some 40,000 miles, and Explorer XII had an apogee of some 50,000 miles.

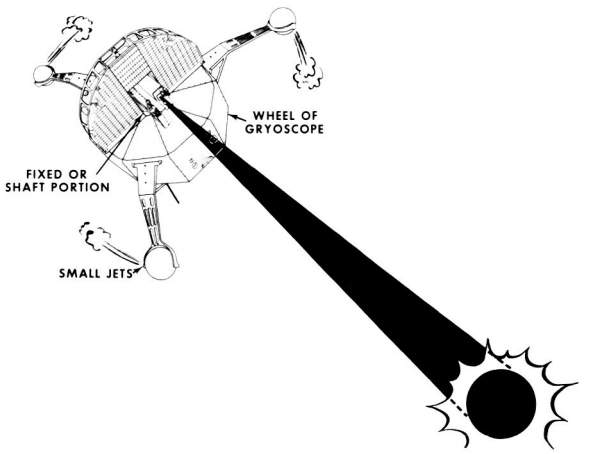


FIGURE 9.—Orbiting Solar Observatory.

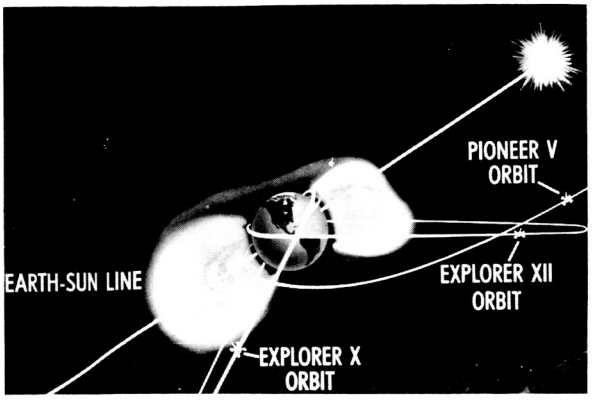


FIGURE 11.—Satellite trajectories for interplanetary studies.

Figure 12 shows the spacecraft themselves. The primary purpose of Explorer X was the measurement of the magnetic field. Since it was expected that this field might range down as low as 1 gamma, $\frac{1}{60,000}$ of the value in this room, it required a very sensitive magnetometer which was mounted on this nonmagnetic plastic boom—away from the magnetic materials in the main structure. Explorer XII had an array of instruments for sensing various types and energy ranges of particles. I believe it would be interesting to digress a bit, to describe some of the instrument techniques for doing this.

The Geiger counter is the simplest instrument for detecting the presence of energetic particles. You will recall that it does this by counting the electrical pulses caused when a particle penetrates the case and causes a change in the conductivity of the enclosed gas. It counts all particles above a given threshold level

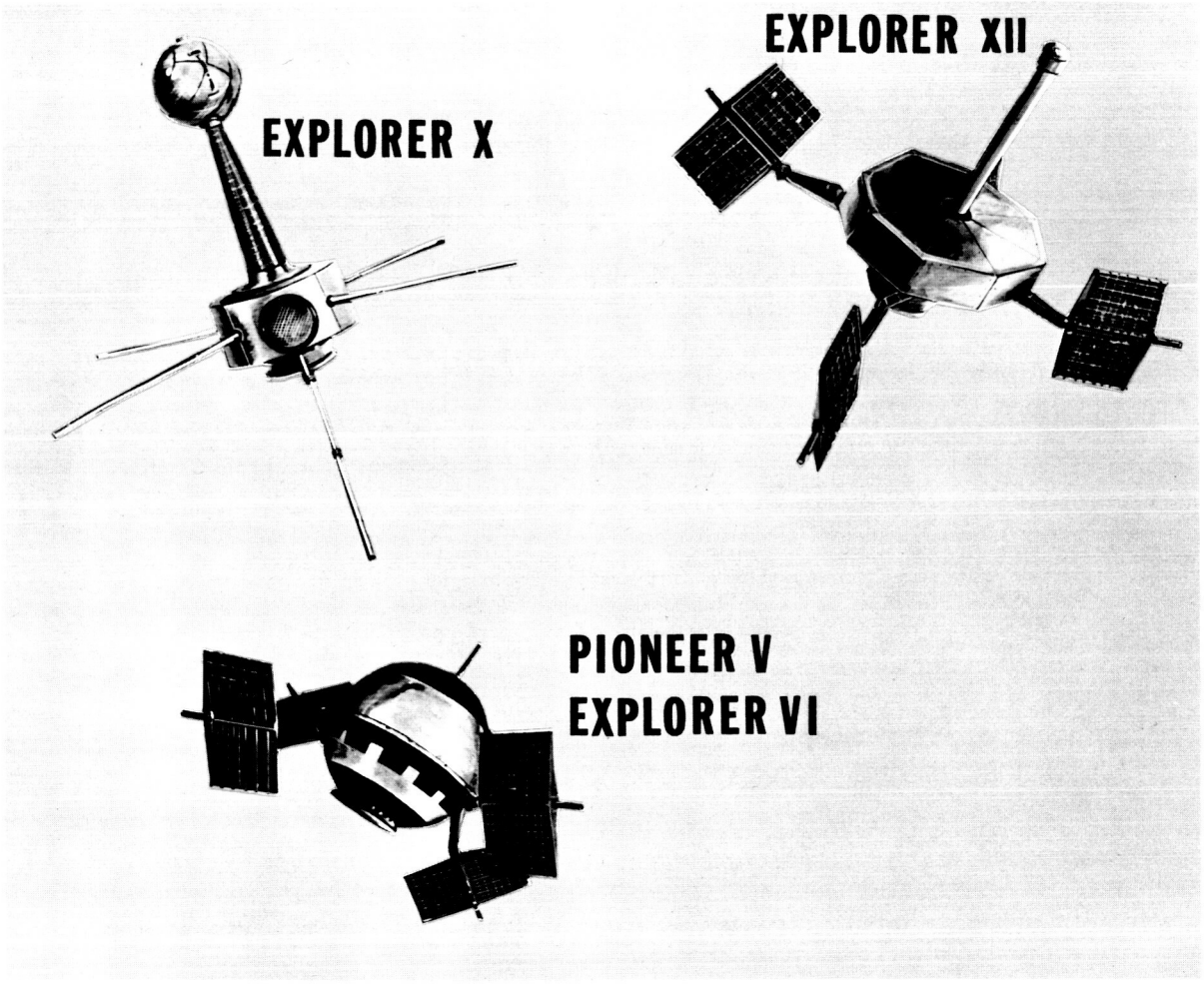


FIGURE 12.—Satellites used in interplanetary studies.

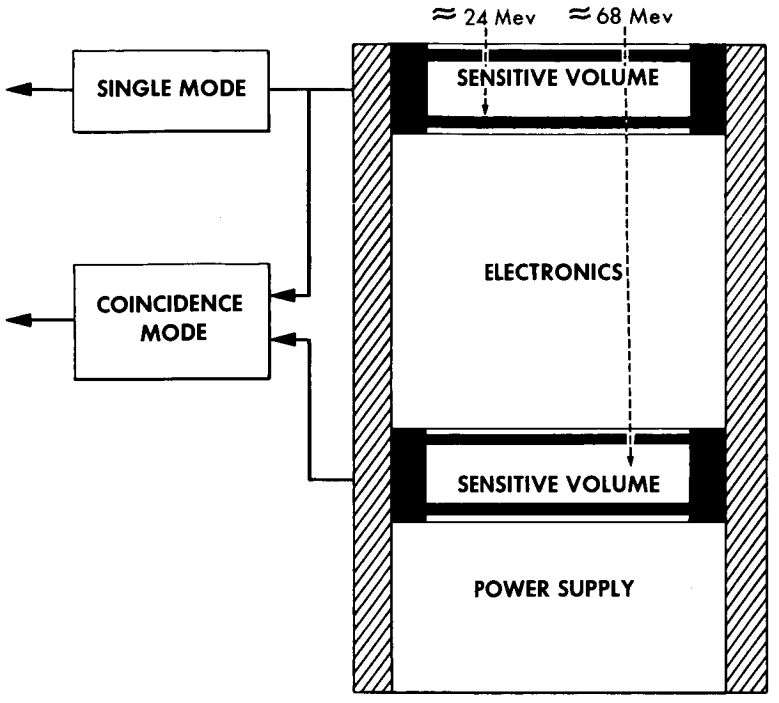


FIGURE 13.—Explorer XII Geiger counter telescope.

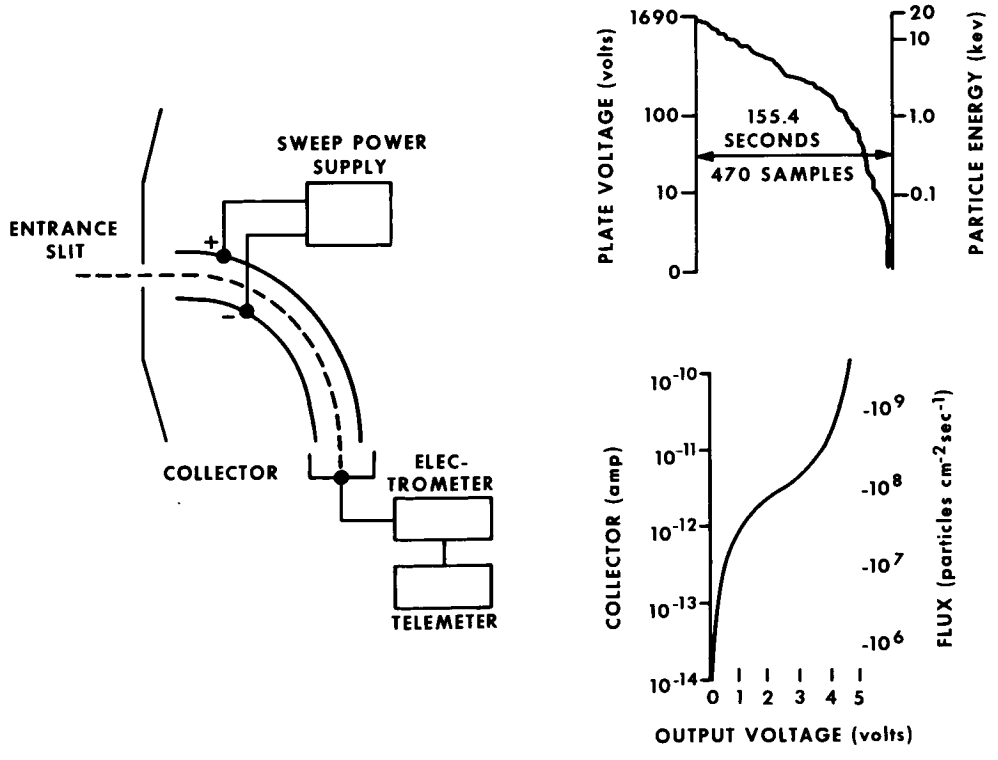


FIGURE 14.—Proton analyzer schematic.

depending on the thickness of the case and surrounding shielding; it does not distinguish between particles or energy levels.

The Geiger counter telescope shown in Figure 13 is a refinement of this instrument. On the single counter it will count all particles with sufficient energy to penetrate either of the sensitized chambers. On the coincidence counter it just records pulses that occur within 2 milliseconds of each other. Thus it counts only those particles with sufficient energy to pass through one sensitized chamber and impinge on the second. By having heavy surrounding shielding, the instrument also has a directional characteristic; so, if it is known in which direction it is pointed, the direction of the incident particle can be identified.

Another instrument, specially designed for detection of low-energy protons, is shown in Figure 14. This instrument is basically a curved-plate electrostatic analyzer with an electrometer output. Particles are admitted through a slit in the surface of the vehicle, and they are energy-selected by the voltage across the curved plates. The electrometer output as a function of plate voltage therefore gives the particle flux as a function of energy. It takes 155 seconds to cover the energy range, and the instrument is sampled by the telemetry every 3/10 second, which gives 470 samples.

Just to give you a feel for the size of such an instrument, it is shown in Figure 15, which is

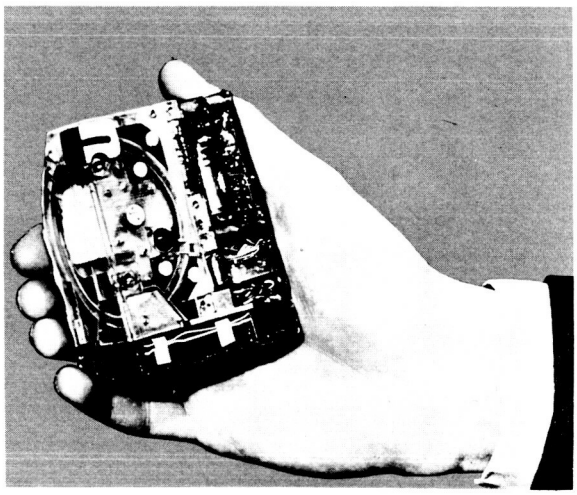


FIGURE 15.—Low-energy proton analyzer.

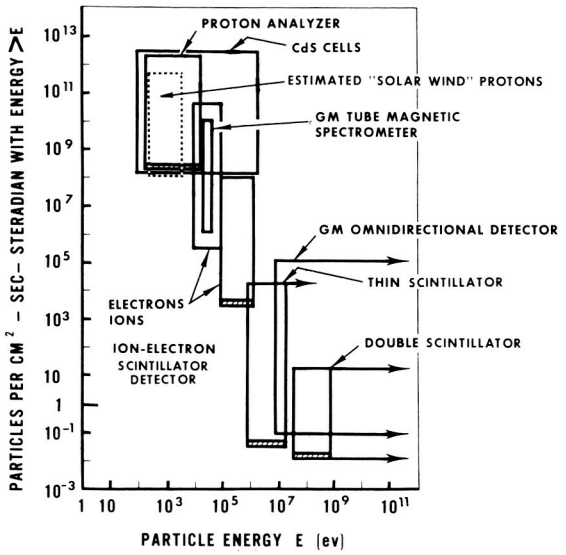


FIGURE 16.—Energetic particle spectra and responses of detectors on Explorer XII.

complete except for power supply. It weighs 0.9 lb, and requires 145 milliwatts of power.

I have only shown these two instruments to illustrate the principle involved. There are a number of other ways of distinguishing between energy levels of particles. Explorer XII, called the "Energetic Particles Satellite," was most completely equipped in this regard. It carried some ten instruments, each for a limited energy range as illustrated by Figure 16. As shown, each instrument was sensitive over a selected energy range. Furthermore, its associated counting equipment was adjusted to an anticipated counting range, dependent on the number of particles expected. This is important. As you know, there is no experimenter close by who can do some adjusting. The range of the instrument must be set correctly at the outset. An instrument which is saturated, or which is too insensitive, is not of much use. When anybody asks me whether man will be useful in space, my reaction is that he would have been very handy on board some of the vehicles we have already launched to do exactly what he does on the ground—that is, make adjustments, and do maintenance. We are looking around for a small, light—and expendable!—man for just this purpose.

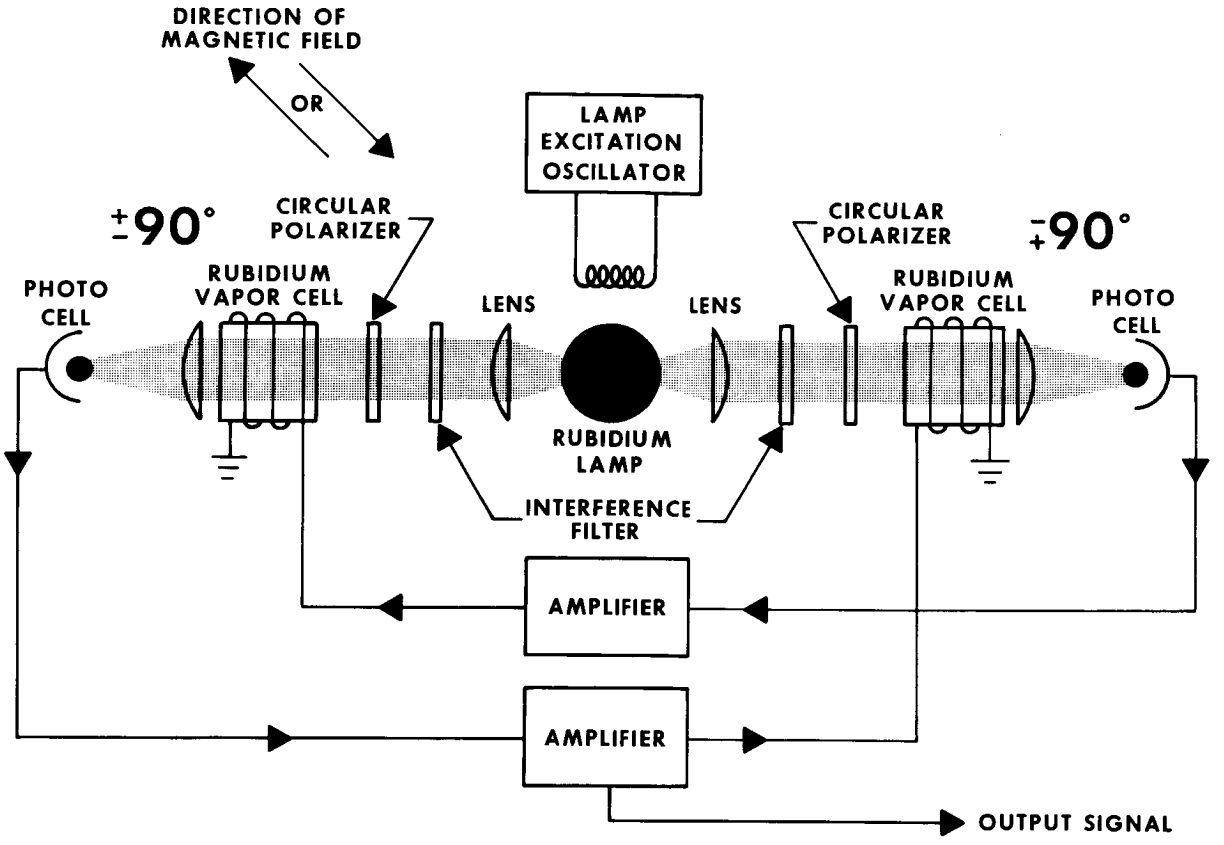


FIGURE 17.—Rubidium-vapor magnetometer.

One other instrument that deserves description is the rubidium magnetometer. As mentioned before, the magnetic field in space has a very low value, so a highly sensitive instrument had to be devised to measure it. Rubidium magnetometers were specially developed for this purpose (Figure 17). The magnetometer involves a rubidium light source, an absorption cell with a tenuous vapor of rubidium gas, a photocell for detecting rubidium light, and electronics for amplifying and feeding back the electrical signal produced by the light. Measurement of the magnetic field comes from the fact that the light is frequency-modulated by the absorbing rubidium vapor. This periodic absorption of light occurs at a rate which depends only on the strength of the magnetic field. The constant relating frequency to field strength is 700 kilocycles per gauss. Thus, in this room, the "rubidium oscillator" would run at about 400 kilocycles and, in a gamma interplanetary field, at about 7 cycles per second.

Now let us take a look at some of the results these instruments have brought back from space. Figure 18 shows a piece of the record obtained by a magnetometer on Explorer X. This piece starts at a point 10.5 radii out and extends through the following 3 days of the trajectory out to 38.5 earth radii.

Before examining the data I would like to emphasize a point mentioned previously. Noted on the bottom of Figure 18 are the world-wide stations located at Johannesburg, South

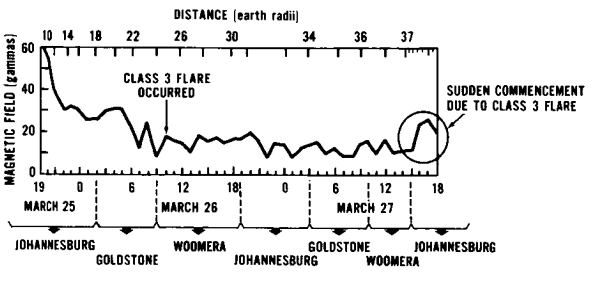


FIGURE 18.—Magnetometer results.

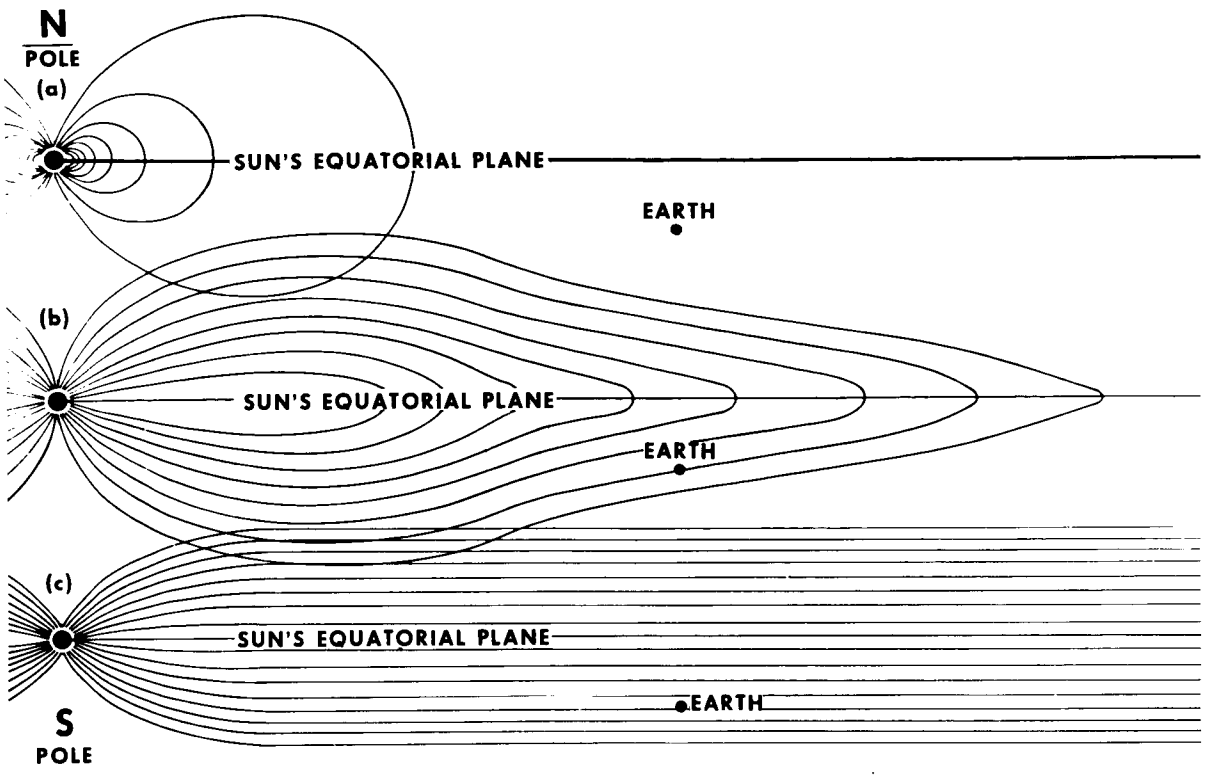


FIGURE 19.—Solar magnetic field: (a) if solar wind did not exist; (b) with moderate solar wind; and (c) with strong solar wind.

Africa; Goldstone, California; and Woomera, Australia, which recorded each particular segment of data. You may wonder why I belabor this point. It is because to me it represents one of the more mundane but important problems of the space age, that is, how to get instruments in as many places tuned and adjusted so that they will give data that dovetail as nicely as this set does. This operation must be correlated within milliseconds, and competently operated by an operational crew who cannot possibly be as familiar with the niceties of the results as is the man who conceived the experiment—who incidentally will, in due course, very critically examine the data. It isn't easy, and we don't always succeed as well as the results imply.

Now to examine the data itself. Note the drop as the spacecraft gets farther and farther from the magnetosphere. It reaches a general level of 20 gammas; this level is considerably higher than that anticipated for the quiescent state in interplanetary space. It also is quite variable in magnitude, as shown on this record, and in direction, as shown on other records not reproduced in Figure 18. Both these conditions fit a "solar wind hypothesis" advocated by some theoreticians who postulate conditions such as are shown in Figure 19. They postulate that during quiet periods the sun's magnetic field is like this, in which case the field strength in the location of Explorer XII would have been in the range of 1 to 5 gammas. However, there are intervals of a "solar breeze" or "wind" shown on the bottom two conditions. In these latter two cases, the magnetic lines are stretched out from the sun. The higher level measured by Explorer X and the somewhat variable conditions tend to support this hypothesis.

Returning to Figure 18, I would like to call your attention to this aspect of the data: Visual observations from the ground indicated that a Class 3 solar flare had occurred. We were most fortunate to have Explorer X outside the magnetosphere at this time. It enabled us to record some unique data on the magnetic field

and plasma flux associated with this flare. The circle shows the effect. Twenty-eight hours after the flare Explorer X noted this marked change in the magnetic field.

This particular section of the Figure 18 data is reproduced in Figure 20. On the upper curve is again shown the magnetic field. You can see the general level that the magnetometer was recording prior to the geomagnetic storm—then the marked change. Down below are the results from the plasma probe instrument which recorded the particle concentration. As you can see, at the same time as the magnetic field jumped, there was a marked increase in the density of plasma flow, showing the close relationship between these two phenomena.

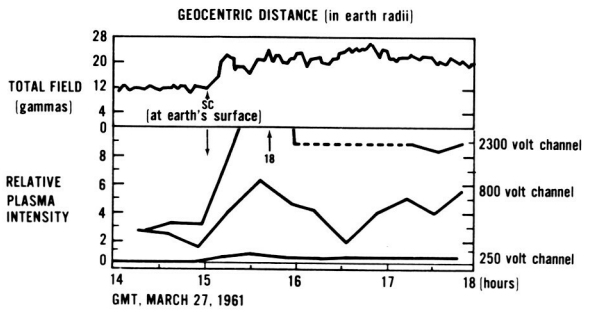


FIGURE 20.—Magnetic field and plasma flow, Explorer X.

Now obviously I have only been able to present a glimpse of the data acquired. When the pieces are put together from Pioneer V, Explorer X, and Explorer XII, the tentative picture begins to emerge. I must hedge my subsequent remarks by saying that this picture is very tentative and it will need much more data before it becomes completely clear. There still remain alternative hypotheses. As a matter of fact this states the case rather mildly. When I tried to sit down with the members of the staff at Goddard who specialize in this area, it seemed as though I had incited a minor riot. However, with this reservation, here is Figure 21.

As the picture indicates, when a solar event—which is an eruption on the surface of the sun—occurs, it sends out a huge tongue of magnetic field lines. According to one hypothesis these lines form in effect a magnetic bottle. Cosmic rays from outer space are excluded by this bottle and bounced off it—and the plasma which erupts from the sun is confined within the bottle. The plasma, which is basically a gas cloud composed of low-energy charged particles, in effect creates a magnetic field which moves along with it. Higher energy particles spiral around and are carried along by these magnetic field lines. It still remains unclear and subject to debate as to whether the particles start out with high energies or acquire much of this energy by being accelerated to high velocities when they are pushed along by the magnetic field. In any event by the time these particles—electrons, protons, and neutrons—reached Pioneer V, Explorer X, and Explorer XII there was a spectrum of energy all the way from relativistic—that is, traveling with the speed of light—on down.

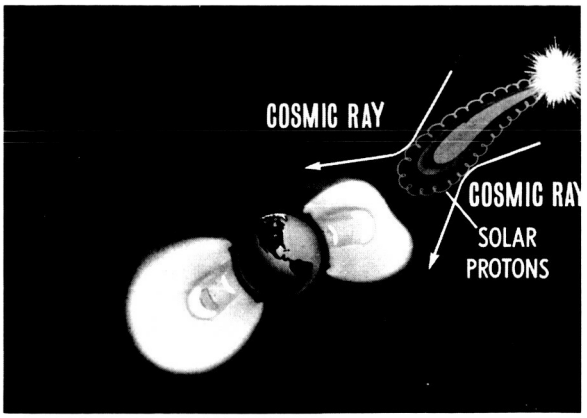


FIGURE 21.—Plasma tongue from solar flare.

As Figure 22 shows, the solar tongue continues to expand, eventually enveloping the magnetosphere. It distorts the magnetosphere

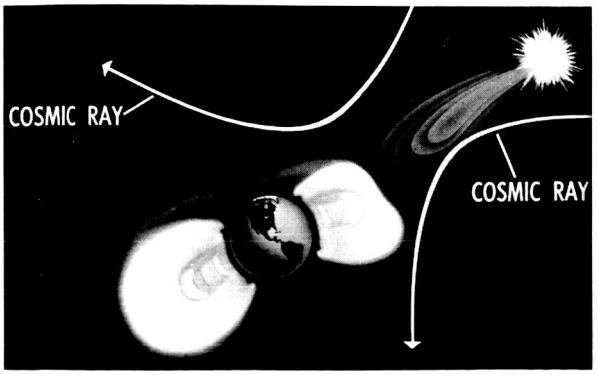


FIGURE 22.—Elongated tongue from solar flare.

as shown here—compressing it at one point, stretching it out into teardrop shape on the opposite side. The particles are deflected by the magnetosphere, and few reach the earth except at the polar cap. Whether these particles then become the primary source of the particle population of the radiation belt is another subject on which there are widely diverse views.

Needless to say, these solar eruptions are of major concern to the people planning manned space flight missions, and measurements such as I have been describing are being used to design the protection which a man will need from exposure to these particles. It would appear that at least for a lunar trip a man can be adequately protected from all but the most extreme events. One objective of our solar studies is to devise a way of predicting when a major event will occur. If this succeeds, manned space shots will be timed to avoid these events, just as a ship avoids a hurricane area at sea.

Next let us turn attention to the near-earth region, to see what goes on inside the magnetosphere. As Figure 23 shows, a number of near-

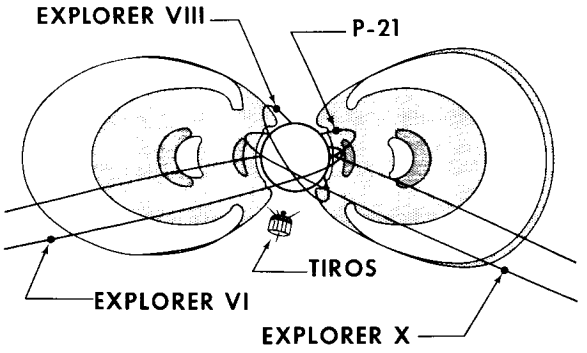


FIGURE 23.—Magnetosphere satellites.

earth satellites have explored this region. They include Explorer VI, VIII, X, P–21, and Vanguard III. Instrumentation on them was generally similar to that which I have already described, with some special types used on Explorer VIII and P–21, which were directed at measurements in the ionosphere. Figure 24 shows the picture that can be pieced together.

In this instance, the magnetic field that controls the distribution of the particles is that of the earth; it is relatively constant and quantitatively understood so that the path of the captured particles is thus reasonably predictable. They ride along these magnetic lines, converge at the magnetic poles, reverse, and wander back to the opposite pole. They come down closest to the earth at these poles, and some investigators think they have an important heating effect on the upper atmosphere, which in turn has a potential influence on the weather. One can stir up a good argument in scientific circles with this last remark, because as yet it is highly speculative. However, the possibilities are very interesting.

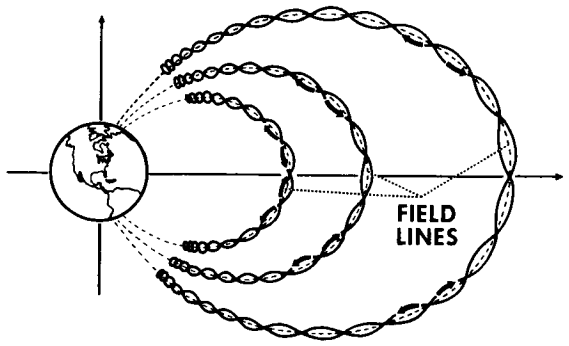


FIGURE 24.—Magnetosphere and belts.

One can also stir up an argument over the source of these particles. One school of thought thinks they are injected into the magnetosphere by the solar flare mechanism I have just described. Others claim an important source is from neutron decay in the upper atmosphere; cosmic rays from outer space or high energy particles impinge in the upper atmosphere, and produce charged electrons and protons, which then are captured by the magnetic lines in the belt.

Satellites since Explorer I, from which Van Allen first identified the belts, have given a more and more detailed picture of the particle population of this belt region. We know the particle population fluctuates, and this fluctuation bears some relation to variable solar conditions. It may be necessary to go through an 11-year solar cycle once or twice before these fluctuations are completely understood. Figure 25 shows an average picture obtained from results to date. It can be considered one huge belt with the characteristics of its population varying from the inner to the outer edge.

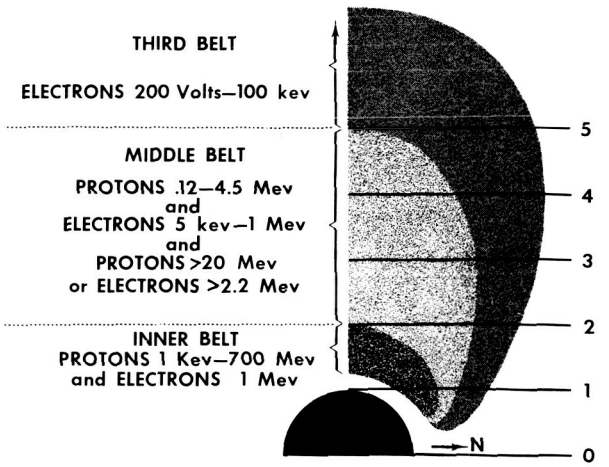


FIGURE 25.—Composition of radiation belt.

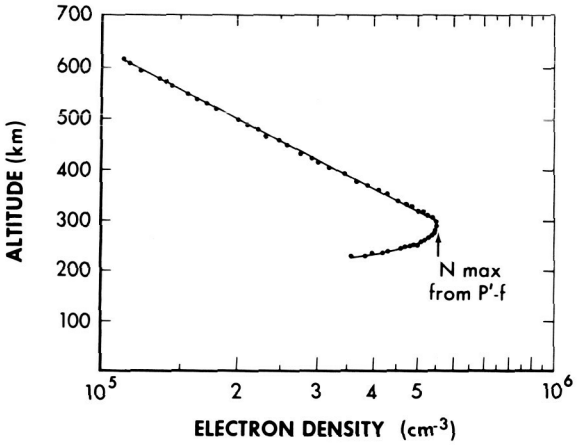


FIGURE 27.—Daytime ionosphere electron density profile.

Information such as shown in Figure 25 will be of considerable importance in planning future communications and weather satellites. These energetic particles not only have a deteriorating effect on a man but they also cut down the lifetime of solar cells, transistors, and other electronic components. Thus, in planning application satellites in which long lifetime is of primary importance, it will be desired to put these satellites into orbits where they are least affected by these particles.

There is still another region of the magnetosphere that has been looked at in considerable detail. Figure 26 shows P–21 and Explorer VIII, which were launched into the ionosphere to determine its characteristics. The ionosphere, as you know, is a region extending roughly from some 40 miles to several thousand miles above the earth. There is special interest in it because of its effect on radio transmission.

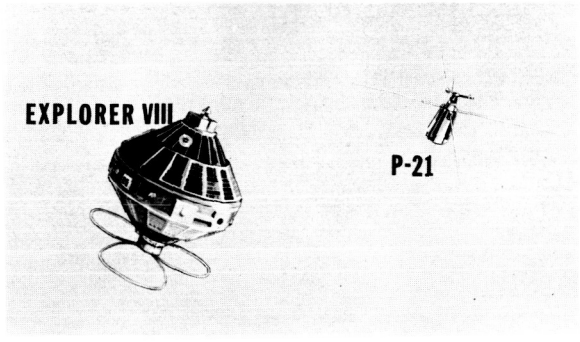


FIGURE 26.—Explorer VIII and P–21.

It is this variable ionized region off which radio waves are bounced to obtain long-distance transmissions.

One set of results obtained from these projects is shown in Figure 27. Shown in Figure 27 is the electron density variation with altitude. The point of maximum density is the feature which influences the long-distance propagation of radio waves. Such detailed knowledge determines the choice of radio frequencies which will be best reflected at any given time. There are some 150 ground stations which can now observe this lower profile. The satellite and sounding rocket information was useful in calibrating these stations in the past and has, in addition, given new information on the upper profile. There is a potential future application use of satellites for this type of measurement; a satellite could cover many areas on the earth not within range of the ground stations.

These high-altitude probes and satellites paid a special dividend in telling us something about the composition of the upper atmosphere. Figure 28 shows on the solid line the measured electron density distribution with altitude; what had been expected is shown by the dotted line. This was based on the general view that at these upper altitudes the main constituent was atomic hydrogen. This deviation is explainable by the existence of a helium layer at these altitudes. This has resulted in a revised view of the composition of the upper atmosphere (Figure 29). As it is now seen, there

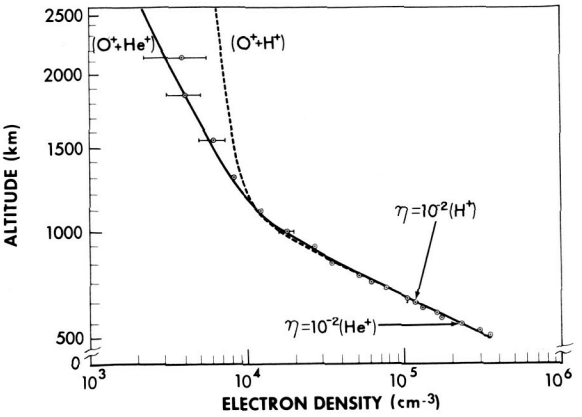


FIGURE 28.—Upper altitude electron distribution.

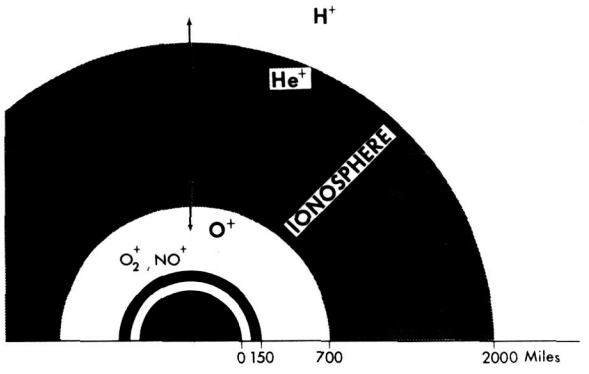


FIGURE 29.—Atmospheric composition.

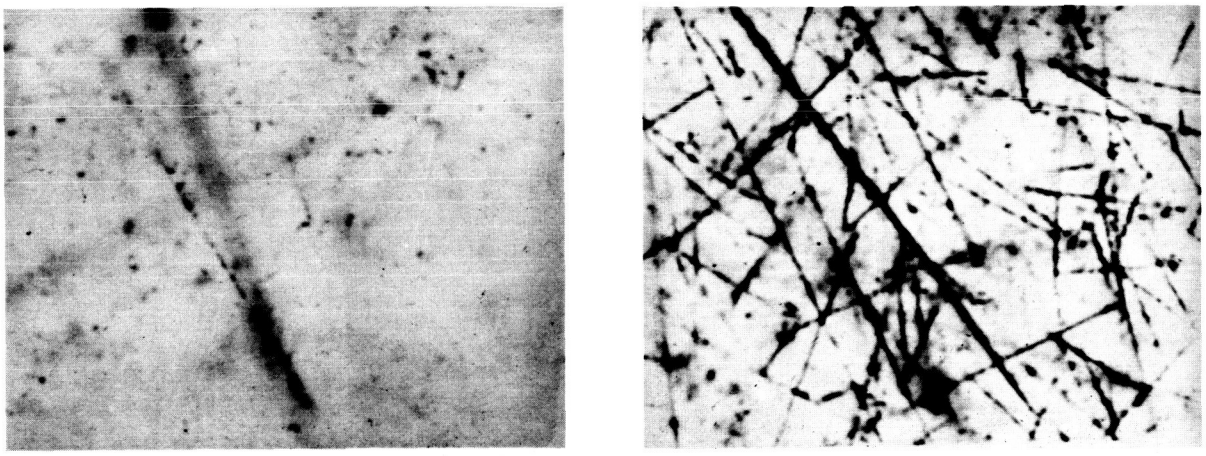
is a layer of ionized helium at altitudes shown in Figure 29, and hydrogen does not dominate until much higher altitudes are reached.

There is still another type of test I would like to discuss, primarily because it is a means by which we reach out and obtain a sample of the sun. This is done from our upper altitude sounding rocket, fired from Fort Churchill, Canada. Figure 30 shows a rather spectacular view of a launch of a Spaerobee rocket up there. Fort Churchill is the launching site for these tests because it is far north where the magnetosphere is the thinnest; it is well situated for the study of polar cap and auroral events by means of sounding rockets. It also is the best place to reach up through the magnetosphere and sample what goes on outside this shield. Even since the advent of satellites, sounding rocket tests of this type have been most useful, because it is fairly easy to recover the payload after it has been up and thus recover the sample for detailed examination.

One method of doing this is the nuclear emulsion technique. All of you who recall the story of the discovery of radium by the Curies are familiar with this technique. You recall how a photographic plate revealed the emission from a piece of radium. Nuclear emulsions are just blocks of the same photo-sensitive emulsion used to coat photographic plates. These are sent up to altitudes of about 90 miles on rockets such as the one shown in Figure 30. Upon recovery, these emulsions are developed and then sectioned to see what has hit them.

Samples of two plates are shown in Figure 31. The one on the left was launched during quiet conditions, and as you can see is relatively unexposed. The one on the right was launched right into the middle of a major auroral display, which coincided with a Class 3 solar flare. The tracks you see are tracks of impinging particles. The long one is the trace of a carbon atom, one of the heavier particles detected. The character of the impinging particle can be

FIGURE 30.—Fort Churchill launch.



(a) Solar quiet.

(b) Solar event.

FIGURE 31.—Solar cosmic ray emulsions.

determined from detailed study of this track. By such a method the relative abundance of these particles can be determined. Figure 32 shows the result. This depicts a statistical sample of particles which some 30 minutes before had been on the sun! I wish we could get samples of the Moon, Venus, and Mars as easily.

The final chapter in my story is Tiros, the weather satellite. Perhaps it is not necessary to tell this chapter, because in contrast to other satellites I have discussed tonight, the story of Tiros is pretty well known. However, it is one of the highlights of our space accomplishments to date, so I would like to talk about it, even if briefly.

Figure 33 shows the manner in which Tiros operates. It looks down on the earth from about 450 miles and can take individual pictures of about 800 miles square of the cloud cover. It also has infrared sensors from which it can measure the temperature distribution of the area below. These data are stored on tape recorders and transmitted to ground stations at San Nicolas Island, Calif., and Wallops Island, Va., when the satellite passes. Figure 34 shows the montage of pictures that can be put together from 96 pictures taken on three successive passes. I am told that pictures such as this have surprised even weathermen with respect to the extensiveness of a cyclonic weather pattern.

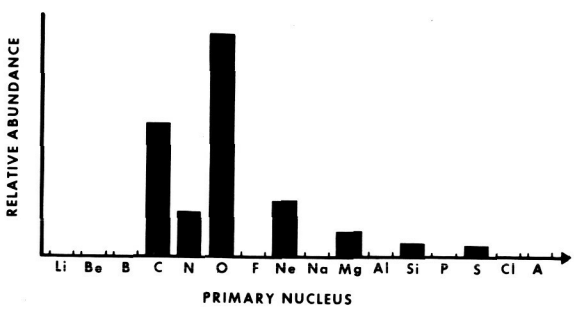


FIGURE 32.—Charge distribution of heavy nuclei in a solar cosmic ray event.

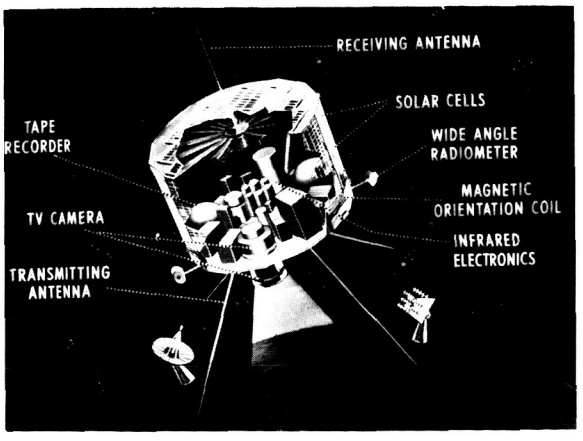


FIGURE 33.—Tiros.

FIGURE 34.—Tiros montage.

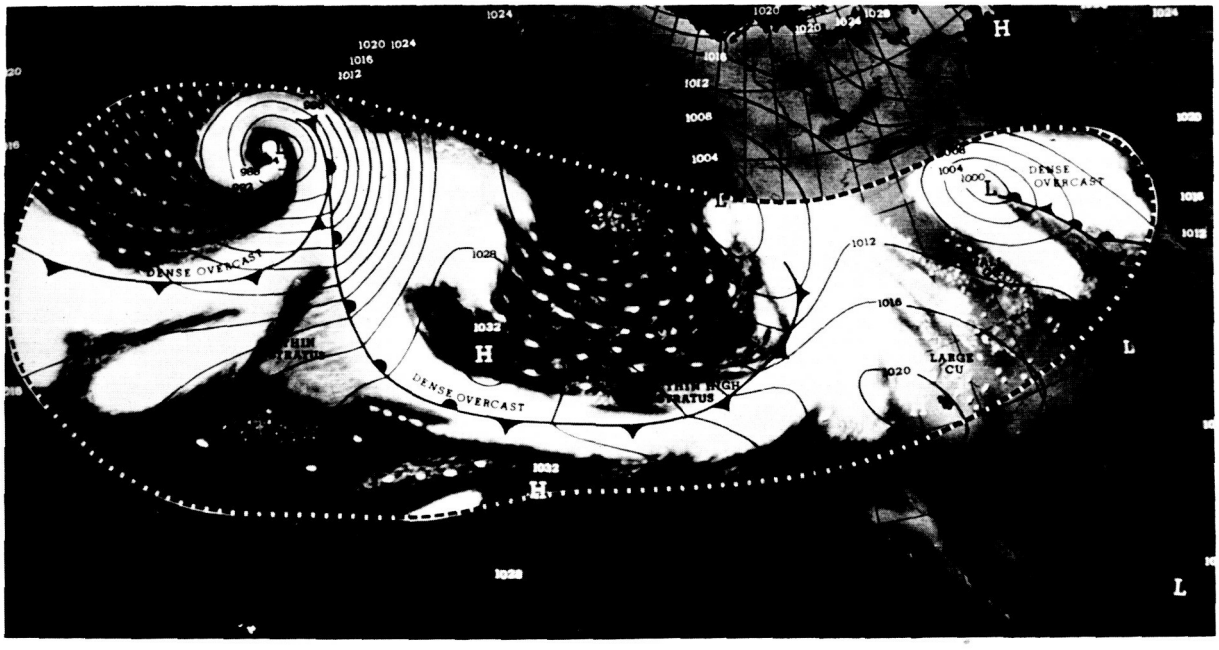


FIGURE 35.—Overlay of Figure 34 on a map.

Figure 35 shows an overlay of this same picture on a map, with the front lines and isobar lines superimposed on the picture. This cloud pattern as you can see extends from the Aleutians to the Great Lakes, some 3000 miles (middle of the picture), and is 1500 miles across. The correspondence of this cloud pattern to the front lines is notable.

Figure 36 shows a world cloud map made from one day of Tiros passes. On it you see the number of hurricane and typhoon disturbances picked up in a single day's passes. This particular cloud analysis spotted Hurricane Esther before it was detected by any other means, and served to alert the hurricane patrol. We hope that, by close examination of the convective cells which grew into Hurricane Esther, more can be learned as to what conditions cause hurricanes. Cloud analyses such as this are distributed over a worldwide weather bureau network and are already serving a useful operational purpose. We are all looking forward to

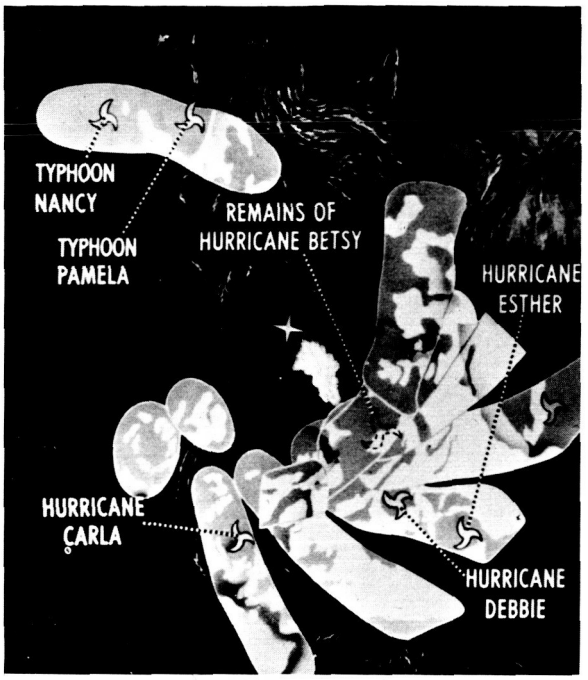


FIGURE 36.—Global cloud analysis, September 11, 1961.

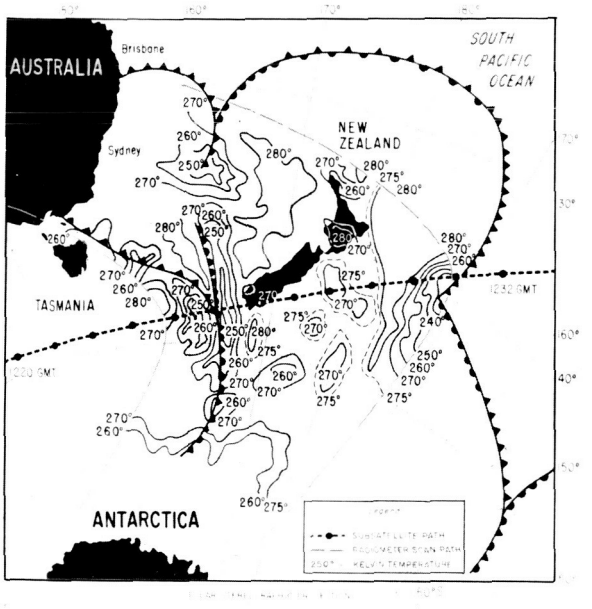


FIGURE 37.—Frontal analysis derived from Tiros II scanning radiometer data, Channel 2 (8–12μ), Orbit O, November 23, 1960.

the more complete cloud coverage which will be furnished when the Tiros successor, Nimbus, comes into general use.

Figure 37 shows the temperature patterns determined from the Tiros infrared data. These are lines of constant temperature. It has been possible to deduce cloud patterns and probable front lines from such data, since the tops of the clouds tend to be cold and the unclouded earth and ocean, warmer. Temperature variations in the atmosphere such as these are in some way related to the dynamics of the weather. It will be interesting in the years to come to see if this relation can be made sufficiently quantitative with the help of data such as this—and used in predicting the movement of main weather patterns.

This is the end of my story. I would like to say in concluding this review that it represents the work not only of many men but of many organizations. The characteristic of space science is such that it spreads across many disciplines and a very broad segment of the scientific fraternity is helping to unravel the meaning of the new scientific data being brought back from outer space. You must recognize the efforts of the orbital mechanicians; physicists with various areas of specialization, astronomers, geologists, and geodesists in the analysis of the results I have described.

I believe that each one of these disciplines has a new frontier. New areas of research are being created by the data which rockets and satellites provided. We surely have just started to realize on their potentialities. But I think I had better end here. Discussion of these future plans would take another 45 minutes.

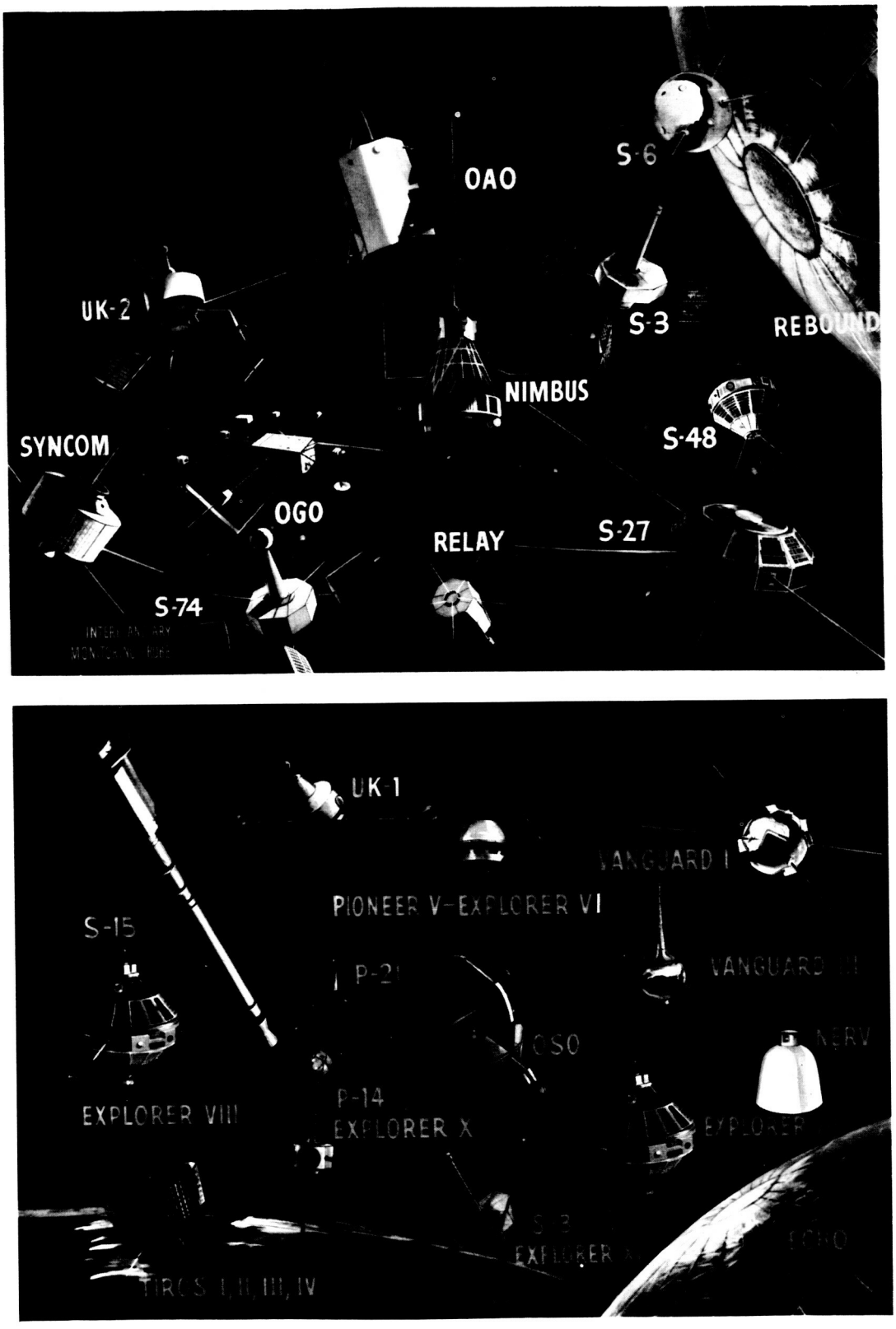


FIGURE 38.—Goddard missions.

Appendix D

EXHIBITS

INDEX TO EXHIBITS

1—Release by Senator J. Glenn Beall, Maryland	Aug. 1, 1958
2—NASA General Directive No. 1	Sept. 25, 1958
3—White House Press Release	Oct. 1, 1958
4—Executive Order No. 10783	Oct. 1, 1958
5—NASA Fact Sheet	Oct. 1, 1958
6—Beltsville Space Center General Notice No. 1	Jan. 15, 1959
7—NASA General Notice	Jan. 22, 1959
8—Beltsville Space Center Memorandum for the Record	Feb. 16, 1959
9—Beltsville Space Center Memorandum for All Concerned	March 6, 1959
10—NASA Memorandum from the Administrator	May 1, 1959
11—GSFC Memorandum to Assistant Directors and Division Chiefs	May 1, 1959
12—NASA News Release No. 59-125	May 1, 1959
13—GSFC News Release No. 3-10-61-5	March 12, 1959
14—GSFC News Release No. 3/14/61-1	March 14, 1961
15—Historical Background and Communications Satellite Act of 1962	(Undated)
16—Public Law 87-624, Communications Satellite Act of 1962	Aug. 31, 1962

EXHIBIT 1

COPY

Release by Senator J. Glenn Beall, Maryland, at Washington, D.C. office
August 1, 1958

U.S. Senator Beall today announced that the new "outer space agency" will establish its laboratory and plant in Maryland. "The location at Greenbelt, Md., is an ideal location for the new Government agency," Senator Beall said, "because of its accessibility to the nation's capital and its proximity to numerous important highways and others to be built."

Senator Beall has been in consultation on the matter of location with officials of the new agency to be known as the National Aeronautical and Space Administration and expressed himself as "greatly pleased with the decision" to locate in Maryland. The senator pointed out that the space laboratory and plant are to be established on land already owned by the federal government, "thus saving the taxpayers what would have been added expense of land purchase."

"The Greenbelt laboratory will employ 650 technicians, mostly electronic engineers and some chemists," Sen. Beall said, adding that, "all research work in connection with outer space programs will be conducted at the Greenbelt installation."

Sen. Beall said further "Construction work on the new plant is expected to get underway immediately in view of the fact that legislation authorizing appropriations of $47,800,000 for the construction and installation of the space projects center (S4208) was passed by the Senate on Friday and is expected to clear the House on Monday."

EXHIBIT 2

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

September 25, 1958

NASA GENERAL DIRECTIVE NO. 1

Subject: Proclamation on organization of the National Aeronautics and Space Administration

On this date I have issued the following Proclamation, to be published in the Federal Register:

A P R O C L A M A T I O N

"1. By virtue of the authority vested in me by the National Aeronautics and Space Act of 1958 (Public Law 85-568, approved July 29, 1958, 72 Stat. 426, 433) I hereby proclaim that as of the close of business September 30, 1958, the National Aeronautics and Space Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by said law.

"2. In accordance with the provisions of the Act, all functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records of the National Advisory Committee for Aeronautics are hereby transferred to the National Aeronautics and Space Administration.

"3. The existing National Advisory Committee for Aeronautics Committees on Aircraft, Missile and Spacecraft Aerodynamics; Aircraft, Missile and Spacecraft Propulsion; Aircraft, Missile and Spacecraft Construction; Aircraft Operating Problems; the Industry Consulting Committee; and the Special Committee on Space Technology and their subcommittees are hereby reconstituted advisory committees to the Administration through December 31, 1958, for the purpose of bringing their current work to an orderly completion.

"4. Existing policies, regulations, authorities, and procedural instructions governing the activities of the National Advisory Committee for Aeronautics, not inconsistent with law, and which are applicable to the activities of the National Aeronautics and Space Administration, shall be continued in effect until superseded or revoked.

"5. The Langley Aeronautical Laboratory, the Ames Aeronautical Laboratory, and the Lewis Flight Propulsion Laboratory are hereby renamed the Langley Research Center, the Ames Research Center, and the Lewis Research Center, respectively.

"DONE at the City of Washington, District of Columbia this 25th day of September in the year Nineteen Hundred and Fifty-Eight."

/s/ T. Keith Glennan

EXHIBIT 3

COPY

FOR RELEASE AT 2:00 P.M., EDT October 1, 1958

James C. Hagerty, Press Secretary to the President

THE WHITE HOUSE

The President today signed an Executive Order transferring certain functions with respect to space activities from the Department of Defense to the new National Aeronautics and Space Administration which comes into existence today under the National Aeronautics and Space Act of 1958 enacted by Congress last July.

Under the Act, the National Aeronautics and Space Administration is to be responsible for aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States shall be the responsibility of the Department of Defense. The determination as to which agency has responsibility for any such activity is to be made by the President with the advice of the National Aeronautics and Space Council.

The present Executive Order transfers from Defense to the National Aeronautics and Space Administration responsibility for non-military space projects such as lunar probes and scientific satellites which have been initiated by the Advanced Research Projects Agency of the Department of Defense pending the establishment of the new civilian agency. It also transfers from Defense certain space-related projects of the Air Force, principally in the field of "super-thrust" propulsion systems which are primarily applicable to future space vehicles. The order also gives to the National Aeronautics and Space Administration responsibility for Project VANGUARD, the United States Scientific Satellite program which has heretofore been the responsibility of the Department of the Navy.

The order transfers from Defense to the NASA the amount of $117 million in connection with the Advanced Research Projects Agency and Air Force projects being transferred. This is the same as the amount anticipated to be transferred for these activities in the initial budget estimates for the National Aeronautics and Space Administration submitted to Congress in August. The particular projects to be transferred are to be identified in one or more supplementary Executive Orders. The transfers of funds necessary in connection with Project Vanguard are to be determined by the Director of the Bureau of the Budget.

Details regarding transfers of records, property, facilities, and civilian personnel, in connection with all of the transfers covered in the present Executive Order, are to be carried out as agreed upon between the National Aeronautics and Space Administration and the Department of Defense.

EXHIBIT 4

COPY

EXECUTIVE ORDER

No. 10783

TRANSFERRING CERTAIN FUNCTIONS FROM THE DEPARTMENT OF DEFENSE TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

By virtue of the authority vested in me by the National Aeronautics and Space Act of 1958 (Public Law 85-568; 72 Stat. 426), and as President of the United States, it is ordered as follows:

Section 1. All functions (including powers, duties, activities, and parts of functions) of the Department of Defense, or of any officer or organizational entity of the Department of Defense, with respect to the following are hereby transferred to the National Aeronautics and Space Administration:

(a) The United States scientific satellite project (Project VANGUARD).

(b) Specific projects of the Advanced Research Projects Agency and of the Department of the Air Force which relate to space activities (including lunar probes, scientific satellites, and super-thrust boosters) within the scope of the functions devolving upon the National Aeronautics and Space Administration under the provisions of the National Aeronautics and Space Act of 1958, and which shall be more particularly described in one or more supplementary Executive orders hereafter issued.

Section 2. (a) The Secretary of the Treasury shall immediately transfer to the appropriation of the National Aeronautics and Space Administration for "Research and Development", from such appropriations of the Department of Defense as the Secretary of Defense shall designate, the following amounts:

(1) In connection with the transfer of functions provided for in section 1 (a) hereof, such amounts as shall be determined by the Director of the Bureau of the Budget pursuant to section 202(b) of the Budget and Accounting Procedures Act of 1950 (31 U.S.C. 581c (b) and section 1(k) of Executive Order No. 10530 of May 11, 1954.

(2) In connection with the transfer of functions of the Advanced Research Projects Agency provided for in section 1(b) hereof, $59,200,000.

(3) In connection with the transfer of functions of the Department of the Air Force provided for in section 1(b) hereof, $57,800,000.

(b) In connection with the transfer of functions provided for in section 1, appropriate transfers of records, property, facilities, and civilian personnel shall be carried out as may be agreed upon from time to time by the National Aeronautics and Space Administration and the Department of Defense.

/s/ DWIGHT D. EISENHOWER

THE WHITE HOUSE

October 1, 1958

# # # # # #

EXHIBIT 5

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington 25, D. C.

For immediate release
Tuesday, October 1, 1958

FACT SHEET ON THE TRANSFER OF CERTAIN FUNCTIONS FROM DEPARTMENT OF DEFENSE TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Administration (NASA) was established by Public Law 85-568 on July 29, 1958. In accordance with the Act, T. Keith Glennan, Administrator of NASA and president-on-leave from Case Institute of Technology, issued a proclamation on September 25, 1958, which stated in part. "I hereby proclaim that the National Aeronautics and Space Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it..."

Prior to the enactment of this legislation, the President wrote to the Secretary of Defense and the Chairman of the National Advisory Committee for Aeronautics concerning his special message to the Congress on April 2, 1958 which recommended establishment of NASA.

In his memorandum, the President said: "The Department of Defense and the National Advisory Committee for Aeronautics should jointly review the pertinent programs currently underway within or planned by the Department, including those authorized by me on March 27, 1958, and should recommend to me as soon as possible which of these programs should be placed under the direction of the new (space) Agency. It should be noted that Public Law 85-325 authorized the Department of Defense for a period of one year; period will come to a close February 12, 1959. Since the new agency will absorb the going organization of the National Advisory Committee

1

EXHIBIT 5 (Cont.)

for Aeronautics, it should be capable of assuming the appropriate programs prior to the date."

The executive order of the President, which transfers certain functions from the Department of Defense to the NASA, is a result of the above stated review.

In accordance with the executive order, the following projects are being transferred to the NASA by the Department of Defense.

1. The United States Scientific Satellite Project (Project VANGUARD). The transfer of this project will include approximately 150 civilian scientific personnel under the direction of Dr. John P. Hagen, Director, Project VANGUARD, Naval Research Laboratory.

2. Four Lunar Probes and their instrumentation, and three satellite projects. These projects are being transferred from the Advanced Research Projects Agency. Two of the Lunar Probes are assigned to the Air Force Ballistic Missile Division and two to the Army Ballistic Missile Agency. The three satellite projects are assigned to the Army Ballistic Missile Agency and call for putting into orbit two inflatable spheres — one 12 feet in diameter, and the other 100 feet in diameter — and a cosmic ray satellite.

The total cost of these ARPA programs is approximately $35.5 million, most of which was funded in Fiscal Year 58. The Fiscal Year 59 funds, necessary to complete these programs, is $9.6 million and will be made available to NASA. Additionally, $49.6 million originally designated for scientific projects, will be transferred to NASA from ARPA.

2

EXHIBIT 5 (Cont.)

3. A number of engine development research programs now being carried on in the Department of the Air Force, will be transferred to NASA. These include basic research programs in such areas as nuclear rocket engines, fluorine engines, and the 1 million lb thrust single chamber engine study and development. As specified in the executive order, $57.8 million will be transferred from the Air Force to NASA for these programs.

The Advanced Research Projects Agency will continue work in activities peculiar to, or primarily associated with, the development of weapons systems for the defense of the United States, including the research and development necessary to make effective projects for the defense of the United States. At the present time, while ARPA has underway projects of considerable priority related to anti-missile defense and solid propellants, it is devoting major attention to continuing military projects, which include satellite programs from warning, navigation, communications, meteorology, and other military exploratory space programs. Space components and activities necessary to these projects, such as the development of super thrust boosters and high energy upper stages are also being carried on by ARPA. A program to put man into space is being pursued jointly by ARPA and NASA.

The ARPA military budget for 1959 is approximately $420 million.

- end -

EXHIBIT 6

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
BELTSVILLE SPACE CENTER
Washington 25, D. C.

4102-AN:lds
15 January 1959

GENERAL NOTICE NO. 1

Subj: Designation as Beltsville Space Center

1. By action of the Administrator, four divisions have been designated as comprising the Beltsville Space Center of the National Aeronautics and Space Administration. The official address is as follows:

National Aeronautics and Space Administration
Beltsville Space Center
4555 Overlook Avenue, S. W.
Washington 25, D. C.

Telephone: JOhnson 2-6610
Dial Code: 172
TWX: WA 134
Military Routing: RBEPRL
Messenger Mail: Stop 10

All members of the Beltsville Space Center are requested to use the new address immediately, and to disseminate it as widely as is necessary. The local Post Office and telephone company are being notified of this action.

2. New stationery has been ordered, and will be distributed as soon as it is received. The stationery masthead will give the address as it appears above, and also will list the three scientific divisions and the telephone and TWX numbers. The Vanguard Division may continue to use its Vanguard stationery until the stock on hand is exhausted or until directed otherwise. Vanguard secretaries should type above the printed masthead the words BELTSVILLE SPACE CENTER.

3. The Space Sciences Division and Vanguard Division will be located at NRL. Vanguard will continue to occupy its present spaces, but there may be some adjustments from time to time, with a view toward achieving better use of what space is available. The Space Sciences Division will move into space being prepared for it in Building 5-7 of the NGF annex, adjacent to NRL Building 71. This move will probably take place within the next three months. The Theoretical Division will remain physically with NASA Headquarters until the Beltsville facilities are ready.

4. All divisions of the Beltsville Space Center will receive their administrative support, generally speaking, from the central administrative

1

EXHIBIT 6 (Cont.)

group being established at NRL under my direction. There will be exceptions to this made necessary by the physical separation of units and individuals. For example, for the immediate future, payrolling, travel, and some supply support for the Theoretical Division will be furnished by Headquarters.

5. The NRL Code Directory will show some listings for the Beltsville Space Center, but unfortunately there is not enough space to show all of the listings we requested. All branch listings could not be accommodated, so no branches will be listed. Service functions will be listed since they are believed to be subject to call frequently enough to be appropriate to the NRL Code Directory. However, we have duplicated, and are distributing with this memorandum, a supplement to the NRL Code Directory. We shall publish a complete directory for your use as soon as we can.

6. The telephone JOhnson 2-6610 is answered at the NRL switchboard by NRL operators. The separate number differs from NRL's only as a matter of identification, but you are requested NOT to use JOhnson 3-6600 unless you are unable to reach the board through JOhnson 2-6610. The change in trunk line number has absolutely no effect on your extension number. The government interdepartmental dial code remains the same as for NRL (172). There will be installed in the near future a two-way tie line between the Headquarters switchboard, and the NRL switchboard, which will permit transfer of incoming calls between the two boards. This means that a party calling JOhnson 2-6610 for a person who is located at Headquarters can have his call transferred to the Headquarters board without having to place a new call, and vice versa.

7. Various notices and instructions will be published from time to time, to advise all personnel of policies and procedures governing the administration of the Beltsville Space Center. Until policies and precedents are established, many actions will be taken on an individual case basis. This is necessary in day-to-day operations; however, the fact that changes in or new procedures are established frequently should come as no surprise under the circumstances.

8. A formal beneficial suggestion program has not yet been established, but constructive suggestions and the pointing out of deficiencies are always welcome.

/s/ T. E. Jenkins
Administrative Officer

Distribution:
Construction Division
Space Sciences Division
Theoretical Division
Vanguard Division

711-534 O - 64 - 14

EXHIBIT 6 (Cont.)

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
BELTSVILLE SPACE CENTER

VANGUARD DIVISION

Code			Bldg.	Room	Tele
4100	Chief, Vanguard Division	Dr. J.P. Hagen	12	369	447
4103	Asst Chief for Operations	CDR L.I. Baird	12	372	673
4104	Management Coordinator	Mr. H.E. Canney, Jr.	12	371A	533
4105	Science Liaison Coordinator	Mr. R.W. Stroup	12	366	445
4120	Vehicle Systems Branch	Mr. D.G. Mazur	2	254A	502
4130	Space Tracking Systems Branch	Mr. J.T. Mengel	42	319	2427
4140	Theory and Planning Staff	Dr. J.W. Siry	30	322	2347
4160	Vanguard Operations Group Manager	Mr. R.H. Gray	AMR ULster 3-4515		
4162	Administrative Assistant	Mr. R.W. Batchelder	AMR ULster 3-2618		
4170	Payload Systems Branch	Mr. N.W. Matthews	60	406	384
4180	Data Systems Branch	Dr. J.P. Hagen	12	369	447

SPACE SCIENCES DIVISION

4200	Chief, Space Sciences Division	Mr. J.W. Townsend, Jr.	Hq.	T602	128-7815
4203	Consultant	Mr. J.C. Seddon	42	415	345
4210	Fields and Particles Branch	Dr. L.H. Meredith	42	314	594
4220	Planetary Atmosphere Branch	Mr. H.E. LaGow	42	424	358
4230	Astronomy Branch	Dr. J.E. Kupperiah, Jr.	30	222	893
4240	Solar Physics Branch	Dr. J.C. Lindsay	Hq.	T605	128-7723
4250	Meteorology Branch	Mr. J.W. Townsend, Jr.*	Hq.	T602	128-7815
4260	Instruments Branch	Mr. K.R. Medrow	42	410	518

THEORETICAL DIVISION

4300	Chief, Theoretical Division	Dr. R. Jastrow	Hq.	T611	128-7721

CONSTRUCTION DIVISION

	Chief, Construction Division	Mr. N.P. Miller	Hq.	T204	128-7523

ADMINISTRATIVE OFFICE

4100A	NASA Administrative Officer	Mr. T.E. Jenkins	12	370	668
4100B	Asst Administrative Officer	Mr. A.P. Nagy	12	371A	2504
4100C	Administrative Services Officer	Mr. R.C. Cowan	12	374	2339
4100D	Personnel Clerk	Mrs. M.C. Dytrt	12	364	2593
4100E	Mail, Records & Documents Clerk	Mrs. P.M. Egan	12	367	798
4100F	Travel and Voucher Clerk	Mrs. H.G. Jackson	12	364	2564
4100G	Supply Clerk	Mr. R.J. Fisher	12	374	2445

APPENDIX D

EXHIBIT 7

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

January 22, 1959

NASA GENERAL NOTICE

Subject: Establishment of Beltsville Space Center

1. The NASA has recently established a new field office to be known as the "Beltsville Space Center." This Center will be operated under the direction of the Director of Space Flight Development - NASA Headquarters (Dr. Abe Silverstein).

2. Pending completion of permanent facilities at Beltsville, Maryland, program activities of the Space Center will be carried out at Washington, D. C. and at the Langley and Lewis Research Centers.

3. During this interim period, official communications with staff members attached to the Center should be addressed as follows:

Office	Address
a. Theoretical Division b. Space Sciences Division	National Aeronautics and Space Administration 1520 H Street, N. W. Washington 25, D. C. (Telephone: Executive 3-3260 - TWX: WA-755)
c. Vanguard Division	National Aeronautics and Space Administration Beltsville Space Center 4555 Overlook Avenue, S. W. Washington 25, D. C. (Telephone: JOhnson 2-6610 - TWX: WA-134)
d. Langley Space Task Group	National Aeronautics and Space Administration Langley Research Center Langley Field, Virginia (Telephone: PArk 3-3325 - TWX: HA-198)
e. Lewis Space Task Group	National Aeronautics and Space Administration Lewis Research Center 21000 Brookpark Road Cleveland 35, Ohio (Telephone: WInton 1-6620 - TWX: CV-520)

/s/ Albert P. Siepert
Director of Business Administration

EXHIBIT 8

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
BELTSVILLE SPACE CENTER
455 OVERLOOK AVENUE, S.W.
WASHINGTON 25, D.C.

SPACE SCIENCES DIVISION
THEORETICAL DIVISION
VANGUARD DIVISION

TELEPHONE; JOHNSON 2-6610
TWX: WA 134
4100A-19:TEJ: vmb
February 16, 1959

MEMORANDUM FOR THE RECORD

Subject: Organization and functions of the Beltsville Space Center; report of observations and stating of implications drawn during conference concerning,held in Mr. Wyatt's office, February 12, 1959

1. Conference Participants:

Robert Gilruth, Assistant Director and Director, Project Mercury
John P. Hagen, Chief, Vanguard Division
Robert Jastrow, Chief, Theoretical Division
Thomas E. Jenkins, Administrative Officer
John W. Townsend, Jr., Chief, Space Sciences Division
Abe Silverstein, Director, Space Flight Development
DeMarquis Wyatt, Assistant to Director of Space Flight Development
Herbert S. Fuhrman, Administrative Assistant to Dr. Silverstein
Al Hodgson, Director of Management

2. Purpose of Meeting: To survey the organization and functions of the Beltsville Space Center as it currently exists; the functions to be performed by the Center in the National Space Program; the organization these functions will require for successful program execution and; to take a very rough cut at the overall staffing problem.

3. Based on this discussion, I am attempting in this memorandum to synthesize the guidelines which can be drawn from the discussion. Attached are organization charts which evolve from the current Space Center groups at scattered locations into an integrated organization at one central physical location.

4. Major functions of the Space Center. It was generally agreed that the space Center will probably perform five major interrelated functions on behalf of NASA as follows:

(1) Project Management. It is generally agreed that Space Center technical staff will perform management functions in connection with NASA space projects, both of the contract and "in-house" variety (or more likely, combination of the two). A project in this sense is a complete application of science and space technology to a given objective such as Man-in-Space,

EXHIBIT 8 (Cont.)

Meteorological Satellite, Lunar Probes, et cetera. In many cases, the feasibility of projects will be studied by the Headquarters technical staff with the input from the Space Center until the gross outline of the job becomes evident. Detailing of the plan of attack and execution of the project will rest primarily with the Space Center provided, of course, the systems responsibility for the project is in-house. The Space Center will also germinate ideas for projects and forward proposals to Headquarters for evaluation and authorization. Management of a project by the Space Center will be augmented by the Headquarters technical staff which will assign a senior project coordinator to expedite the work of the project and to help resolve management problems requiring Headquarters attention and support.

(2) Research. The Space Center will perform research (a), as required to meet the gaps in current knowledge to form a base for future ideas and applications and (b), research-in-space in all the scientific disciplines as dictated by the expanding knowledge of space phenomena.

(3) Development and Fabrication. The Space Center will design and develop, including prototype fabrication, components and systems which advance the state of the art of space technology and for specific project application. This in-house development effort is required to translate the ideas of scientists and engineers into hardware where the contracting process would prove infeasible. For instance, the development of payload systems of a highly experimental nature requiring many stages of development, each dependent upon advanced techniques which in themselves are developed as the hardware takes shape, can best be done with in-house development and fabrication facilities available on the spot and under the detailed direction of the staff scientists and engineers. In both industry and government experience shows that this type of effort is very difficult to "farm out" on contract.

(4) Advance Planning. The Space Center is and will continue to be staffed by leaders in their respective fields who will germinate many of the ideas necessary to the future program of space science and exploration. As the practitioners of the art, they will, like many good contractors, develop as a fruitful source of ideas. In fact, the current National Space Program, as expressed in various NASA documents, is in large part a synthesis of ideas emanating from the NASA staff. All of the ideas expressed in the space program are not, of course, exclusive with NASA personnel, but the program does express the broad competence of the staff. It is expected, as is currently the case, that Space Center staff will continue to participate in the formulation of the program and in this respect act as a technical staff to Headquarters.

(5) Operations. The Space Center will be in charge of technical operations in the field in all programs assigned to the Space Center. These programs will include in-house space center projects plus projects carried mostly on contract from Headquarters but technically monitored by the Space Center. Space Center technical terms at the launching sites will, of course, be under the direction and control of project and functional heads within the Space Center. Space communications and tracking will a prime operational responsibility of the

EXHIBIT 8 (Cont.)

Center. This function includes data handling, both orbital and telemetered scientific.

5. It was concluded that to satisfy the questions in the mind of the Administrator we should immediately come up with (a), an interim plan of organization and operations to assure full effectiveness and integration into the program of the groups which now exist for the Space Center and (b), a tentative ultimate plan of organization and functions to show what the Space Center may look like three years from now.

6. Functional versus Project Organization within the Space Center. These two fundamental bases for organization were discussed at some length in terms of what would be the best form of organization for the Space Center.

It was concluded that each of these bases of organization has merit and each has some drawbacks. Both in industry and government, outstanding examples of each can be cited.

(1) Functional Organization. By this is meant organizing the Space Center into sub-elements identified with across-the-board scientific or space technology disciplines. For instance, guidance and control, astronomy, data handling, scientific instrumentation, and propulsion. In an R&D institution, this form of organization is necessary to advancing the basic state of various disciplines and arts, and functional applied areas. Specialists in a given area are grouped and are interested in evolving new knowledge and techniques without reference to a proconceived specific application, but with the full knowledge that whatever gaps are covered will benefit the program cross the board. This type of organization is generally stable and develops specialists who can be tapped as consultants by the applied projects. Effort organized along this line, when staffed by competent people who are really research people, creates the store of knowledge which is absolutely required if program stagnation is to be prevented.

The disadvantage of this type of organization is that unless it is modified or subverted for this purpose, it results in diffuse project management when a major project is planed in the organization

(2) Project Organization. A Project manager should have under his control or as his responsibility all of the necessary resources prepared to fulfill the project's mission. In a functional organization dependent, of course, on personalities and other factors, the project manager is handicapped from "managing" and "directing" and is apt to become something of a coordinator-expediter. If the institution is charged with carrying out several major projects the competition among projects for specialists' services, in-house central technical service support, and even use of certain contractors must be delineated by management by formal assignment and delegation. The easiest way to accomplish this is to assign resources including personnel to the project

EXHIBIT 8 (Cont.)

under the direct control of the project director. The "project" should use central services where they exist and it is feasible.

It is concluded from the above that the Beltsville organization should be based on functional lines with organizational flexibility allowing the Center to organize for major or "macro" projects. Small or "micro" projects can and should be carried in the functional divisions.

7. Program Requirements. The program currently assigned and contemplated for the Space Center has not yet been detailed in full. However, the major efforts which are listed below indicate a very large and active program which will require a great deal of contracting plus a heterogenous, competent, and sizeable Space Center staff. Some of these assignments, active or to become active in the next eighteen months, are:

(1) Science Program

155 sounding rockets of various types
30 satellites
15 probes

(2) Application Satellites

- Communications and Meteorological, 6 or 7 vehicles,
- Geodetic - number of satellites unknown at this time,
- Other Vanguard Division follow-on programs - vehicles and numbers as yet undetermined.

(3) Project Mercury

- Phase I
- Phase II

(4) Vehicles and Engines

Vega, Centaur, Thor-Vanguard (Thor-Delta), Juno V (1.5 meg bundle), Nova (1.6 meg engine known currently as 1.0 meg engine).

(5) Global Range and Operations

- Space Communications and Tracking
- Operational Telemetering
- Ranges - Wallops, AMR, MR

8. Members of Personnel Required. Currently, all segments of the organization, in terms of personnel numbers, are merely nuclei of the ultimate staffs needed to do the jobs to be done. There is the feeling that budget planning for the next fiscal year does not include adequate numbers for the Space Center to carry out its mission. In general the program managers, that is Division Heads, feel that if adequate numbers of competent personnel can be brought on the staff, this is more important than

EXHIBIT 8 (Cont.)

studying at this point how the Space Center is to be organized. This feeling is not to be interpreted as a cry for anarchy or lack of organization, but as an expression that thinking about the Space Center sometimes seems to ignore the fact that the Space Center is already very much a going concern. Geographical dispersion and logistic support currently supplied in part by NRL, Langley, and Lewis tends to cloud thinking on immediate future requirements. The fact that the physical plant does not exist should not deny the existence of the going major components of the organization. The general feeling was expressed that we are headed for trouble in 1960 unless the complement figures, in particular, are raised above levels being cited currently.

9. Space Center functions in terms of existing nucleus capabilities. The Space Center is not starting from scratch in organizing a technical competence. The five groups at the Division level now in operation have a nucleus capability to perform work organized functionally or by project in the following areas:

(1) Space Sciences,
(2) Vehicle Systems,
(3) Theoretical Research and Support,
(4) Instrumentation Support
(5) Payload Systems,
(6) Data Handling and Techniques,
(7) Communications and Tracking,
(8) Operations.

10. My suggestions for organization of the Space Center:

(1) To fully integrate it into the National Space Program,
(2) To fully capture and utilize the nuclei of existing capabilities, and
(3) To fulfill the potential which the senior personnel of the Center feel can be brought into being realistically,

are attached hereto with explanatory notes.

/s/ T. E. JENKINS
Administrative Officer

5

APPENDIX D

EXHIBIT 9

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

BELTSVILLE SPACE CENTER

6 March 1959

MEMORANDUM FOR ALL CONCERNED

FROM : T. E. Jenkins, Administrative Officer

SUBJ : BSC Divisions' Authorized Personnel Complements, FY 1959; summary of recent revisions

1. To sum up the current situation with respect to Beltsville Space Center division approved personnel complements (ceiling points):

a. We requested a total of 342 ceiling points to cover the Vanguard Division, including 42 for my Administrative staff;

b. Dr. Silverstein approved an allocation against the Vanguard money of 400 but to include 90 for Space Sciences Division. Dr. Silverstein also promised Mr. Townsend he could get an additional 10 from the 400 if he needs it by 30 June. Space Sciences Division then can go to a total of 100;

c. Dr. Jastrow requested relief for the Theoretical Division of 10 points. Abe approved 6 points for Jastrow (plus 30 points carried against S&E for a total of 36);

d. In summary, the total of 400 ceiling points authorized against Vanguard funds reserved on Headquarters' books is tentatively allocated as follows:

Total authorized	400
Space Sciences Division (Townsend)	100
Theoretical Division (Jastrow)	6
Vanguard Division (Hagen)	252
Beltsville Administrative Office (Jenkins)	42
Total	400

2. Vanguard Division, in all likelihood, will require more than 252 points prior to 30 June 1959. In the financial summary we presented to Dr. Silverstein there is money reserved to cover some additional points. In fonecon with Dr. Silverstein I agreed it was too early to forecast how successful Vanguard recruiting efforts will be, but all indications are that they will be highly successful. Currently, physical work space is the limiting factor. Vanguard will not exceed this ceiling without specifically getting an approval by the Director, Space Flight Development.

3. Controls. I am taking steps through the Beltsville personnel office to control accessions within the above figures. By this memorandum Division Heads (Hagen, Jastrow, Townsend) are advised that all PAR Form 52s must be submitted to the Beltsville Personnel Office, Attention Code 4100B (Al Nagy) for approval within authorized complement and money before commitments to hire can be considered firm with the candidate. If the total ceiling of 400 proves inadequate I will request additional authorizations from Dr. Silverstein based on division justifications.

/s/ T. E. JENKINS
Administrative Office

Distribution:

Headquarters:
A. Silverstein
A. Siepert
D. Wyatt
A. Hodgson
R. Ulmer (3)
R. Lacklen (2)
H. Fuhrman

Beltsville:
J. Hagen
J. Townsend
R. Jastrow
A. Nagy
B. Sisco
L. Best
B. Cowan

EXHIBIT 10

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
1520 H STREET NORTHWEST
WASHINGTON 25, D.C.

OFFICE OF THE ADMINISTRATOR

May 1, 1959

MEMORANDUM from the Administrator

Subject: Functions and Authority - Goddard Space Flight Center (GSFC)

1. Purpose of this Memorandum.

   a. To establish the Goddard Space Flight Center, Greenbelt, Maryland

   b. To provide a statement of functions and authority for the Goddard Space Flight Center.

2. Functions. The Goddard Space Flight Center is assigned the following functions:

   a. Conducting advanced planning and theoretical studies leading to the development of payloads for scientific and manned space flights.

   b. Conducting necessary supporting research in scientific payloads, applications systems, instrumentation, communications, guidance, and vehicles.

   c. Developing payloads for approved scientific programs, applications programs, and manned space flights.

   d. Developing, subject to specific approval in each case, vehicles to launch payloads.

   e. Supervising Goddard Space Flight Center flight operations, integrating the activities of all participants as necessary to accomplish missions successfully.

1

EXHIBIT 10 (Cont.)

f. Supervising tracking, data acquisition, communications and computing operations for the provision of orbital and reduced flight data from satellites and space vehicles for NASA space flight programs assigned to or monitored by the Center and for other space programs as requested by the Director of Space Flight Development.

g. Interpreting results of flight programs for which the Goddard Space Flight Center is responsible.

h. Furnishing technical management of projects, including monitoring of contractors, to insure timely and economical accomplishment of objectives.

i. Exercising such procurement and contract administration authority as may be delegated by the Director, Office of Business Administration.

j. Upon request by the Director of Space Flight Development, providing support for space program activities of other organizations, e.g., military establishments of Department of Defense.

k. Reporting on the status of approved programs and recommending changes or modifications as necessary to meet program goals and schedules.

l. Providing necessary administrative and management support as required for carrying out assigned programs.

3. Responsibility of Director, GSFC. The Director, GSFC, reports directly to the Director of Space Flight Development and is responsible for the exercise of the functions assigned to the Goddard Space Flight Center.

4. Scope of Authority. The Director, GSFC, is authorized and directed to take such action as is necessary to carry out the responsibilities assigned to him within the limitations of this and other official NASA communications and issuances.

EXHIBIT 10 (Cont.)

5. Relationships with Other Officials. In performing the functions assigned to him, the Director, GSFC, is responsible for recognizing the responsibility and authority of heads of divisions and offices, Headquarters and for assuring that actions he may take are properly coordinated with Headquarters groups having joint interests and are in accordance with NASA policies.

6. Approval of Organization. The basic organization of the GSFC is outlined on the attached organization chart. Modifications or changes in basic organization structure are subject to the approval of the Director, Space Flight Development and the Administrator, NASA.

/s/ T. Keith Glennan
Administrator

Encl
Chart

EXHIBIT 11

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER

4100A-89:TEJ:vmb
May 1, 1959

MEMORANDUM TO ASSISTANT DIRECTORS AND DIVISION CHIEFS
Subject: Organization and Functions of the Goddard Space Flight Center

1. Effective May 1, 1959 the Beltsville Space Center became the Goddard Space Flight Center. The change in name accompanies the first formal announcement of the Space Flight Center organization, mission, functions, and appointments of many of the key personnel.

2. Attached is the official statement on organization and functions accompanied by the official organization chart for the Space Flight Center. As with most documents of this type, the wording in some cases may carry different meaning to different people. Therefore, it should be stated that the spelling out of the mission was not done to be restrictive so far as activities conducted by the Space Center are concerned. The mission is broad and the functions certainly spell out more responsibilities than we can fully carry out or will be able to carry out until our capabilities have been built up much beyond the point where they now exist.

3. There are many administrative details to be sorted out and published to gear internal operations to the new organization structure. Such workaday things as time cards, directories, job order numbers, delegations of authority, et cetera are in the process of being published. We did as much preplanning work as possible, but since all organization details were not nailed down until a very late hour it will take us a couple of days to publish the necessary instructions. In the meantime, you are advised that all previous instructions remain in effect until superseded. For instance, job order and account numbers to be used on time cards, stubs, et cetera will remain the same until changed by specific notice. This paragraph is not to be interpreted in any way as abrogating the authority of any appointed official.

(signed)
T. E. JENKINS
Administrative Officer

EXHIBIT 11 (Cont.)

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON 25, D.C.

ORGANIZATION OF ACTIVITIES
OF GODDARD SPACE FLIGHT CENTER

Mission and Functions

1. Operating as an integral part of the NASA space flight program, under the overall guidance and direction of the Director of Space Flight Development, NASA Headquarters, the Goddard Space Flight Center will be a major field arm of NASA. It will carry out assigned missions in the planning, research, developmental, and operational phases of the nation's space flight program. Specifically, personnel of the Center shall:

a) Conduct advanced planning and theoretical studies leading to the development of payloads for scientific and manned space flights.

b) Conduct necessary supporting research in scientific payloads, applications systems, instrumentation, communications, guidance, and vehicles.

c) Develop payloads for approved scientific programs, applications programs, and manned space flights.

d) Develop, subject to specific approval in each case, vehicles to launch payloads.

e) Supervise Goddard Space Flight Center flight operations, integrating the activities of all participants as necessary to accomplish missions successfully.

f) Supervise tracking, data acquisition, communications and computing operations for the provision of orbital and reduced flight data from satellites and space vehicles for NASA space flight programs assigned to or monitored by the Center and for other space programs as requested by the Director of Space Flight Development.

g) Interpret results of flight programs for which the Goddard Space Flight Center is responsible.

h) Furnish technical management of projects, including monitoring of contractors, to insure timely and economical accomplishment of objectives. In this connection, the Goddard Space Flight Center will execute contracts, in accordance with delegated authority, for performance of work necessary to accomplish program objectives.

1

EXHIBIT 11 (Cont.)

i) Upon request by the Director of Space Flight Development, provide support for space program activities of other organizations, e.g., military establishments of Department of Defense.

2. These missions will be carried out through the execution of major functions as described below:

a) Advance Planning. The Goddard Space Flight Center staff will include leaders in the several space science fields who will be responsible for the formulation of ideas and concepts which are essential to the effectiveness of the space flight program. This advance planning will be of value to the Space Flight Center in carrying out its mission. Also, the Space Flight Center will assist and advise the Office of Space Flight Development, NASA Headquarters, in the formulation of the national space flight program.

b) Research. The Space Flight Center will perform two broad types of research: scientific and engineering research necessary to serve as a base for future ideas and applications; and research in the disciplines of the space sciences as a basis for acquiring ever-increasing knowledge of space phenomena.

c) Development and Fabrication. The Goddard Space Flight Center will design and develop, including prototype fabrication, components and systems which advance the state-of-the-art of space technology or which have direct project application. A part of this activity will be in-house, while the remainder will be on contract. The development and fabrication activities to be handled in-house will normally be those which cannot be handled as economically, expeditiously, or effectively by a contractor, either because they are so intimately related to other activities being carried out at the Center or because they involve matters so fundamental to major in-house project operations of the Center that they cannot readily be separated therefrom.

d) Operations. The Space Flight Center personnel will be in charge of technical operations in the field for all programs assigned to the Center. These programs will include in-house projects as well as those on contract for which the Center has the monitoring responsibility. Space Flight Center technical teams at launches will be under the technical direction and control of project and functional heads within the Center. Space communications and tracking, as well as data reduction and interpretation, will be operational responsibilities of the Space Flight Center. For other NASA space flight programs, the Center, upon request of the Director of Space Flight Development, will assume operational responsibility for tracking, data acquisition, communications and computing operations and for the provision of orbital and reduced flight data from satellites and space vehicles.

EXHIBIT 11 (Cont.)

e) Project Management. The Space Flight Center will be responsible for the management of projects and parts of projects as necessary for the accomplishment of its assigned missions. A project in this sense is the application of scientific and engineering technology to a specified objective, such as man-in-space, meteorological satellites, lunar probes, and so forth. Ideas for projects may originate in Headquarters, in the NASA field organizations, or from other sources. Projects will be undertaken following authorization by Headquarters. Projects will be carried out on either an in-house or a contract basis. Monitoring responsibility may from time to time be assigned to the Space Flight Center on contracts let by NASA Headquarters. Project officers will be designated from the NASA Headquarters staff to advise and assist the Goddard Space Flight Center in projects execution and in resolving management problems which require Headquarters attention and support.

Relationships

1. With Office of Space Flight Development, NASA Headquarters

a) The Goddard Space Flight Center will participate with the Office of Space Flight Development in the definition and establishment of national program objectives.

b) Within the defined national program objectives, the Goddard Space Flight Center will carry the full responsibility for accomplishing the missions assigned to it, subject to such technical advice and assistance as the Office of Space Flight Development, NASA Headquarters, may provide.

c) The Goddard Space Flight Center will keep the Office of Space Flight Development fully informed at all times concerning problems arising and progress made in connection with the Center's assigned responsibilities.

d) The Goddard Space Flight Center will be responsible for its own internal administration, in accordance with the provisions of applicable statutes and policies, procedures, and regulations issued by NASA Headquarters.

2. With JPL

The missions and functions of the Goddard Space Flight Center and the Jet Propulsion Laboratory complement each other. There will be no contractual relationships between the two, but there will be frequent interchange of data and technical information to the extent warranted by the common interests of both or as necessary for the operations of either. The

EXHIBIT 11 (Cont.)

relationships between these two organizations, both active in the space flight development field, will be essentially the same as those which exist between the NASA Research Centers.

3. With NASA Research Centers

The Goddard Space Flight Center will have no formal relationships with the NASA Research Centers except through NASA Headquarters. The channel of communications in matters requiring formal action will normally be: Goddard Space Flight Center to Office of Space Flight Development, NASA Headquarters, to Office of Aeronautical and Space Research, NASA Headquarters, to the Research Centers. Such matters originating in the Research Centers will be referred to the Goddard Space Flight Center through the same offices, but in opposite sequence. Interchange of information and data, however, may be carried on freely between the Space Flight Center and the Research Centers without regard to these channels, except that information copies shall be furnished to the Office of Space Flight Development and the Office of Aeronautical and Space Research, NASA Headquarters.

4. With Contractors

The Goddard Space Flight Center will be authorized to enter into contractual arrangements with private contractors in accordance with applicable NASA policies, regulations, and procedures. Subject to the limitations imposed by such policies, regulations, and procedures, the Goddard Space Flight Center will have the authority to develop contract specifications, including engineering design where appropriate, invite bids, evaluate proposals, make awards, and monitor performance.

5. With Governmental Agencies

There will be contractual relationships between the Goddard Space Flight Center and other governmental agencies as authorized by NASA Headquarters.

Organization of the Goddard Space Flight Center

1. Attached is an organization chart reflecting the components which are proposed as major segments of the Goddard Space Flight Center. This organization provides:

a) Integration of the missions and functions of the Goddard Space Flight Center with the national space program objectives.

b) Coordination of the direction of the scientific and technical functions of the Center with the supporting engineering and business management activities.

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EXHIBIT 11 (Cont.)

c) A staffing pattern that anticipates and provides for the orderly integration of the personnel and functions now separately located at Langley Research Center, Lewis Research Center, and Naval Research Laboratory.

d) A management structure capable of full execution of both technical and support activities with the same degree of delegated responsibility that characterizes the operation of other major NASA field establishments.

2. The scientific and technical programs of the Center are grouped under three Assistant Directors.

a) The Assistant Director, Space Science and Satellite Applications, will be responsible for:

1) Space Sciences Division - responsible for conduct of a broad program of basic research in the space sciences through the use of experiments carried in rockets, earth satellites, and space probes.

2) Theoretical Division - responsible for conduct of a broad program of study and research in phases of theoretical physics, mathematics, and mechanics associated with the exploration of space.

3) Payload Systems Division - responsible for integration of scientific experiments and equipments into complete earth satellites and space probes; conducts research and development in the fields of space environment and special electronic devices such as telemetering systems, command receivers, control circuitry, and power supplies; designs, fabricates, constructs, and tests satellite and probe space systems.

4) Satellite Applications Systems Division- responsible for research and development on applications systems, including: applications satellites, such as the meteorological, communications, and geodetic satellites; space techniques such as advanced control and stabilization systems; and space and booster vehicle systems.

b) The Assistant Director, Tracking and Data Systems, will be responsible for:

EXHIBIT 11 (Cont.)

1) Tracking Systems Division - responsible for research and development on new systems for tracking, data acquisition, and communications between satellites and/or space vehicles and ground receiving stations; provides evaluation capability for all system proposals plus calibration capability for systems which are in operation; provides technical and engineering support for all modifications and enlargements of technical equipment at the field stations, by furnishing prototype equipment, contract monitoring, and field installation and technical inspection services.

2) Data Systems Division - responsible for the application of data reduction techniques to: launching of vehicles, orbit calculation, and satellite and space probe scientific data; conducts research and development on new data handling techniques as required for Space Flight Center programs, and furnishes theoretical support for all phases of data techniques and analyses; responsible for data reduction and computation activities connected with NASA space flight programs assigned to, or monitored by, personnel of the Center; provides computation service for all areas of the Center as required, as requested by Director of Space Flight Development, assumes operational responsibility for data reduction and computation activities for other NASA or Department of Defense programs.

3) Operational Support Division- responsible for establishment and continuous operation of global tracking, data acquisition, and communications network, furnishing personnel and technical and logistic support therefore; operates control center of the Goddard Space Flight Center, furnishes continuing technical support of space flight operations, including range support and operations necessary to initiate communication, tracking and data sequences after vehicle launch; coordinates operations to assure utilization of the net and adequate service to user teams, both inside and outside NASA.

c) The Assistant Director, Manned Satellites, will be responsible for:

1) Flight Systems Division - responsible for conceptual design, integration

EXHIBIT 11 (Cont.)

and performance of complete manned space flight systems, including on-board equipment and subsystems; carries out preliminary design and performance analyses and specifies requirements for advanced systems; monitors or performs the required basic and applied research in support of space flight systems.

2) Operations Division - responsible for establishing operational procedures associated with the launch, in-orbit, reentry and recovery phases of manned space flight missions; accomplishes detailed trajectory analyses associated with each mission in the Mercury Program to ensure that test plans and test schedules are met; conducts necessary pre-flight checking and in-flight monitoring in order to maintain flight safety; selects and trains flight crews appropriate for each flight test.

3) Engineering and Specifications Division - responsible for engineering studies of proposed manned space flight vehicles and components to determine their feasibility; prepares specifications and cost estimates; supplies and monitors technical information required for the procurement and administration of contracts.

3. There is also included in the organization a Special Projects Group, currently identified as the Lewis Space Task Group, which has program responsibility for engineering development and design of a special high energy rocket stage.

4. The Office of Business Administration will provide the Center with the full range of central administrative support functions, including: personnel administration; budget and financial administration; plant and personnel security programs; management analysis activities; administrative services, including plant and fire protection; procurement and supply, including contract administration; and technical information, including library services.

5. The Office of Technical Services initially will include only the construction group which is already in existence. As construction progresses, however, and the Space Flight Center becomes a physical reality, it will be necessary to staff this Office to perform the full range of its functions. These will include: fabrication and shop operations; construction and repair; buildings and grounds maintenance; utilities operations; automotive operations, and industrial safety.

/s/ Abe Silverstein
Director of Space Flight Development

Attachment
1 Chart

Date: 1 May 1959

7

EXHIBIT 12

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington 25, D. C.

NASA RELEASE NO. 59-125
EX 3-3260
Ext. 7827

FOR RELEASE:
Friday P.M.
May 1, 1959

NASA'S NEW SPACE PROJECTS FACILITY NAMED
GODDARD SPACE FLIGHT CENTER

T. Keith Glennan, NASA Administrator, announced today the Government's space projects center at Greenbelt, Maryland, will be named the Goddard Space Flight Center in commemoration of Robert H. Goddard, American pioneer in rocket research.

The Goodard Space Flight Center, under the overall guidance of the Director of Space Flight Development at NASA headquarters, will perform basic space research and will be responsible for the development of satellites, space probes and vehicles, tracking, communications, and data reduction systems. In addition, the facility will eventually be a command control center for NASA space flight operations.

The organization of NASA's new Space Center includes a director, not yet appointed; three major research and development groups, each headed by an assistant director; and business administration and technical services departments.

John W. Townsend, Jr., formerly Chief of NASA's Space Sciences Division, has been appointed Assistant Director for Space Science and Satellite Applications. Divisions reporting to him are: Space Sciences, Theoretical, Satellite Applications Systems, and Payload Systems. The Vanguard Operations Coordinating Group also reports to

EXHIBIT 12 (Cont.)

Townsend. Beginning today, the staff of the Vanguard Division will be integrated into other major NASA space flight projects.

John T. Mengel, former head of the Space Tracking Systems Branch in the Vanguard Division, has been named Assistant Director for Tracking and Data Systems. Reporting to him are the Tracking Systems, Data Systems, and Operational Support Divisions.

Robert R. Gilruth is the Center's Assistant Director for Manned Satellites. He currently heads the Mercury manned space flight project. Divisions under his direction are: Flight Systems, Engineering and Specifications, and Operations.

Michael J. Vaccaro, formerly assistant head of the Administrative Management Office and Personnel Director at the Lewis Research Center, Cleveland, Ohio, has been appointed Business Manager of the Space Center. The head of Technical Services has not been announced.

The Goddard Space Flight Center will be built on an approximately 550-acre tract acquired from the Government's Beltsville Agricultural Center, north of Washington, D. C. Located east of the Baltimore-Washington Parkway, the site is bounded on the south by Glendale Road.

The contract for the first two major buildings at the Center -- Space Projects Building and Research Projects Laboratory -- was let April 10, 1959, to Norair Engineering Corporation of Washington, D. C., at a total cost of $2,882,577. These two-story buildings, scheduled for completion in mid-1960, will total about 100,000 square feet of laboratory and office floor space. They will house a staff of about

EXHIBIT 12 (Cont.)

450. The remainder of the staff of the Goddard Space Flight Center will be housed at the U. S. Naval Research Laboratory in Washington, and at the Langley Research Center, Langley Field, Virginia, until the completion of the facility.

- END -

EXHIBIT 13

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NEWS RELEASE

GODDARD SPACE FLIGHT CENTER
GREENBELT, MD.

OFFICE OF PUBLIC INFORMATION
PHONE: GRanite 4-9000, Ex. 555

RELEASE NO. 3-10-61-5

FOR RELEASE
SUNDAY A.M.'s
March 12, 1961

The National Aeronautics and Space Administration will dedicate its $27-million Goddard Space Flight Center at Greenbelt, Md., on March 16. The Dedication date marks the 35th anniversary of the world's first flight of a liquid-propelled rocket engine by Dr. Robert H. Goddard, father of American rocketry, for whom the Center has been named.

The Center, which will be completed by the end of next year, is the first completely new complex to be constructed and staffed for the peaceful exploration of space since NASA was established in November, 1958.

Center personnel conceive, develop and fabricate satellite and sounding rocket instrumentation that probe space in the immediate vicinity of the earth. The Center also has the world-wide responsibility for tracking, communications and data analysis for both manned and unmanned spacecraft.

Several hundred invited guests are expected to attend the Dedication ceremony which will begin at 2 P.M. The ceremony will be followed by a guided one and one-half hour tour of the Center's facilities. The Dedication will not be open to the public. Open house for employees and their families will be held Saturday, March 18 from 10:30 A.M. to 3:30 P.M. It is planned to hold a public open house later as the Center nears completion.

The Center will be dedicated by Dr. Detlev Wulf Bronk, President of the National Academy of Sciences. He will be introduced by James E. Webb, NASA Administrator. An honored guest will be Mrs. Esther Goddard, widow of the Clark University rocket pioneer. She will be presented a Congressional Gold Medal, authorized by the 86th Congress. The presentation will be made jointly by Senator Robert S. Kerr (D-Okla.), Chairman of the Senate Committee on Aeronautical and Space Sciences, and Overton Brooks (D-La.), Chairman of the House Committee on Science and Astronautics.

Mrs. Goddard and Dr. Bronk will unveil a sculpture of Dr. Goddard which later will be placed in the Center's Administration Building. It was created by Washington sculptor, Joseph Anthony Atchison, noted for his creative work in the Shrine of the Immaculate Conception in Washington, the World Flight Memorial for the Smithsonian Institution, and the Second Inaugural Medal of Franklin D. Roosevelt.

EXHIBIT 13 (Cont.)

RELEASE NO. 3-10-61-5

Release for Sunday A.M.'s
March 12, 1961

Invocation for the ceremonies will be delivered by The Rev. Kenneth B. Wyatt, pastor of the Greenbelt Community Church. The benediction will be said by Father Victor J. Dowgiallo, pastor of St. Hugh's Catholic Church, Greenbelt.

The tours, both for invited guests and the 'open house' for employees and their families, will embrace the full spectrum of the Center's activities. Included will be a Control Room demonstration with simulation of a pre-rocket launch and countdown procedures, followed by a simulated satellite injection into orbit.

Lectures will be given on the Center's operation of global satellite tracking networks, including Minitrack and Project Mercury. The Center's cooperative role for the international exploration of space will be explained. Guests will see an animated miniature tracking station, and a scale model of the forthcoming S-51 spacecraft being instrumented by the United Kingdom which will be flown by Goddard.

There will be an extensive display of spacecraft instrumentation along with many of the Goddard Center's family of sounding rockets used for scientific experiments. Included will be an Iris Sounding Rocket and an Aerobee 150A with a new attitude (or pointing) control system. A similar rocket will be fired March 15 for the first test of controlling a rocket's three axes of pitch, yaw and roll. The experiment also will carry equipment aimed at measuring gamma ray intensities and the solar illumination.

Other models will include the Tiros weather satellite; the P-14 magnetometer (or radiation-counting) spacecraft; the S-3 energetic particles measurement satellite; the Explorer VIII and Vanguard I. Guests will also see a demonstration of a micrometeorite detector.

Tours will be conducted through the Center's extensive laboratory facilities where guests will see vacuum, vibration and spin-balancing equipment used to simulate space environmental conditions.

EXHIBIT 14

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NEWS RELEASE

GODDARD
SPACE FLIGHT CENTER
GREENBELT, MD.

OFFICE OF PUBLIC INFORMATION
PHONE: GRanite 4-9000, Ex. 555

RELEASE NO. 3/14/61-1

GODDARD SPACE FLIGHT CENTER

FACT SHEET

The National Aeronautics and Space Administration GODDARD SPACE FLIGHT CENTER is the first completely new scientific center created since the NASA was established October 1, 1958. It is the nation's newest facility devoted exclusively to the peaceful exploration of space.

Formally organized on May 1, 1959, it was named for the late Dr. Robert H. Goddard, recognized as the Father of American Rocketry. He designed, developed and flew the world's first liquid-fuel rocket.

The Center was dedicated March 16, 1961, the Thirty-fifth Anniversary of that launching by Dr. Goddard.

The Goddard Space Flight Center is one of ten field laboratory facilities of the N.A.S.A., and is one of several integrated units under the direction of the Office of Space Flight Programs. The Center carries out assigned missions in the theoretical, planning, research, development and operational phases of space flight, utilizing laboratory studies and experiments, sounding rockets, earth satellites and space probes.

Organization

Dr. Harry J. Goett is Director of the Goddard Space Flight Center. Principal operating executive is Eugene W. Wasielewski, Associate Director. Other major officials and their duties are:

Mr. John W. Townsend, Jr., Assistant Director, Space Sciences and Satellite Applications, supervises four divisions:

a. The Space Sciences Division, headed by Dr. Leslie H. Meredith, conducts basic research in the space sciences through the use of experiments carried in rocket sondes, earth satellites, and space probes. It supports the NASA National Sounding Rocket Program and provides management and contract monitoring.

- More -

EXHIBIT 14 (Cont.)

b. The Theoretical Division, headed by Dr. Robert Jastrow, studies and conducts research in theoretical physics, mathematics, and mechanics associated with space exploration. Included are special analytical problems involving the use of large computers. The Division is now organizing an Institute for Space Studies in New York City, where it will draw on talent from Universities and Research Groups.

c. The Payload Systems Division, headed by N. Whitney Matthews, is responsible for the integration of experiments and equipments into complete earth satellites and space probes; and for the basic satellite structure, thermal balance, and integrity of the entire system through all anticipated environmental conditions.

d. The Satellite Applications Division, headed by D. G. Mazur is concerned with research, preliminary design and project management of meteorological, communications, and geodetic satellites.

Mr. John T. Mengel, Assistant Director, Tracking and Data Systems. This office supervises three divisions:

a. Tracking Systems Division, headed by Clarence A. Schroeder, which concerns itself with research and development of new tracking, data acquisition and communications systems between space vehicles and ground receiving stations.

b. The Data Systems Division, headed by Dr. Charles V.L. Smith, applies data reduction techniques to launchings of vehicles, orbit calculations, and satellite and space probe findings.

c. The Operational Support Division, headed by Fred S. Friel, establishes and operates NASA's global tracking, data acquisition, and communications network.

d. The Theory and Analysis Staff, headed by Dr. Joseph W. Siry, provides orbital and system analysis support for tracking and data systems.

Dr. Michael J. Vaccaro, Assistant Director, Business Administration. This office provides business management support functions, including personnel, budget and finance, security, procurement and supply, administrative, and public information.

Mr. Leopold Winkler, Chief, Office of Technical Services. This office is charged with fabrication and shop operation, construction and repair, buildings and grounds maintenance, utilities and automotive operation, and industrial safety.

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EXHIBIT 14 (Cont.)

Release No. 3/14/61-1
Goddard Space Flight Center Fact Sheet Page 3

The Goddard Mission

Specific areas of Goddard's responsibilities are:

. Advanced planning and theoretical studies leading to development of spacecraft for manned and unmanned scientific space investigations. This work includes formulation of concepts and ideas essential to the effectiveness of the NASA program.

. Supporting research in spacecraft, applications systems, instrumentation, communications, guidance, and rocket vehicles as assigned.

. Development and fabrication of spacecraft for scientific and applications programs and manned space flight. The Center designs, develops, and fabricates prototypes of components and systems to advance space technology or to foster practical applications. Although the Center directs all such work, most of it is contracted out to industry and universities. For reasons of economy, urgency, efficiency or effectiveness, about fifteen percent of such activities are performed internally by the Center.

. Development and supervision of worldwide tracking, data acquisition, communications and computing operations for all NASA space programs except deep space probes.

. Interpretation of results of experiments under Goddard management.

. Management of projects, including technical direction and the execution and monitoring of contracts.

Staff and Facilities

Located on a 550-acre tract of land near Greenbelt, Maryland, about fifteen miles from Washington, D. C., the physical plant when completed in 1962 will consist of eight facilities costing approximately $27 million. Facilities now in operation are: Space Projects Building, Research Projects Laboratory and Central Flight Control and Operations.

First elements of the Goddard Staff were drawn from the Vanguard Project Team of the U. S. Naval Research Laboratory. The complement now numbers more than 1,300 and will total 1,800 by the end of 1961. It is expected to rise to about 2,000 when the Center construction is completed.

Facilities at the Center will enable scientists and engineers to subject payloads to the complete range of flight environments without having to risk an actual launch with untried hardware.

- More -

EXHIBIT 14 (Cont.)

As one example, the Center's environmental test facilities include centrifuges, dynamic balancing machines, vibration machines, and thermal vacuum chambers. Of the last, there will be four when the present construction program is completed--including some of the largest chambers in the country. The largest will measure thirty feet by forty feet and will be capable of producing the complete range of near-space vacuum and temperature conditions.

Scientific Exploration in Space

Goddard Center programs embrace unmanned scientific research and exploration of space; study of the earth's upper atmosphere; study of the earth itself from the space viewpoint; unmanned technological utilization of space for practical purposes, such as weather forecasting and global telephone, radio and television communications; and near-space tracking and data handling.

During the present decade, in the execution of this program, the Center plans to launch at least ninety-six scientific satellites and twenty-eight applications satellites.

Launching of sounding rockets and space probes will total hundreds. Purchases of sounding rockets in the current fiscal year include 22 Aerobees, 18 Nike-Asps, 20 Nike-Cajuns, 4 Argo D-4's (Javelins), 2 Argo D-8's (Journeyman), and 5 Iris. Frequency of rocket launchings is expected to increase steadily over the next decade, particularly in support of the Tiros-Nimbus weather satellite programs.

The Center plays a major role in NASA's international cooperation for the peaceful exploration of space. Scientists of twenty-one nations are participating in the Tiros meteorological satellite experiments; Canada is designing the payload for a swept-frequency topside ionosphere sounder satellite to be launched and tracked by Goddard; United Kingdom will supply the experiments for an international ionosphere satellite to be built and launched by Goddard; and a number of scientists and technicians are in cooperative study and training at the Center.

Accomplishments

Since its organization, the Goddard staff has made significant contributions to knowledge of space and the earth.

The Vanguard III satellite, designed and launched by the Goddard, Staff provided information on the distribution and intensity of the earth's magnetic fields; detailed location of the lower edge of the Van Allen Great Radiation Belt, and made an accurate count of micrometeorite impacts.

- More -

EXHIBIT 14 (Cont.)

The Explorer VII satellite, in which Goddard played a key role in cooperation with the NASA Marshall Space Flight Center and the Jet Propulsion Laboratory, provided valuable information on radiation balance, Lyman-Alpha x-rays, heavy primary rays, micrometeorite impacts, solar exposure, temperature, magnetic storms and detected large-scale weather patterns.

The Pioneer V space probe experiment, jointly conducted by Goddard and the Space Technology Laboratories, transmitted valuable data on solar flares, particle energies and their distribution, and magnetic fields. The probe, second U. S. spacecraft to orbit the sun, transmitted data to earth from a record distance of 22,500,000 miles.

The Tiros I and II meteorological satellite experiments, launched by the Delta rocket developed under Goddard supervision, provided many thousands of photographs of the earth's cloud cover and mapped radiation and heat balance on a global scale.

Echo I, the first passive communications satellite, was launched in cooperation with the NASA Langley Research Center. This 100 foot inflatable sphere proved the feasibility of communications over long distances by bouncing radio signals off its reflective surface. Messages were transmitted across the continent and across the Atlantic and photographs were sent by the same means.

The Explorer VIII satellite, another joint project of Goddard, the Jet Propulsion Laboratory and Marshall Space Flight Center, carried out the first intensive direct measurements of the earth's ionosphere, by measuring concentrations of charged particles and their temperatures.

In its sounding rocket programs, Goddard made the first measurements of auroral absorption events and solar proton beams; first flew an alkali vapor magnetometer to measure the earth's magnetic field at altitudes above 600 miles, and obtained the first ultraviolet stellar spectra.

The NERV, or Nuclear Emulsion Recovery Vehicle, launched by sounding rocket from the Pacific Missile Range to a height of 1,260 miles, was recovered from the ocean. The experiment produced exact measurements of the lower Van Allen Great Radiation Belt.

- End -

EXHIBIT 15

COPY

HISTORICAL BACKGROUND AND COMMUNICATIONS SATELLITE ACT OF 1962

On August 31, 1962, the President signed H.R. 11040, and the Communications Satellite Act of 1962 became law. At the time of signing, the President congratulated the Congress for "a step of historic importance." He stated further: "It promises significant benefits to our own people and to the whole world. Its purpose is to establish a commercial communications system, utilizing space satellites which will serve our needs and those of other countries and contribute to world peace and understanding."

Major steps in the development of this legislation were as follows:

a. June 15, 1961, the President asked the Chairman of the National Aeronautics and Space Council to have recommendations prepared for communications satellite policy. Under direction of the Council staff, interagency meetings were held; policy recommendations were drafted; and those recommendations were acted upon unanimously by the Council.

b. July 14, 1961, the President approved and released the policy statement, which stressed the public interest objectives in obtaining a global system as soon as technically feasible. This policy stated that private ownership and operation of the U.S. portion of the system is favored, provided that the public interest is adequately protected through opportunities for foreign participation, non-discriminatory use of and equitable access to the system, and effective competition in the acquisition of equipment and in the structure of ownership and control.

c. In the fall of 1961, the President requested the staff of the Council to draft recommendations in order that the communications satellite policy could be effectively implemented. Under the direction of the Council staff, interagency drafting sessions were held, and the proposed bill was prepared and transmitted to the President.

d. February 7, 1962, the President sent the proposed legislation to the Congress and, in his accompanying message, urged that it be given prompt and favorable consideration.

e. Extensive hearings were held in the Congress. Six different committees called witnesses and participated in a thorough examination of the communications satellite policy and proposed legislation. After such committee actions, explanation and debate took place prior to votes in both the House and the Senate. The House passed a bill by a 354 to 9 vote on

EXHIBIT 15 (Cont.)

May 3;the Senate passed its corresponding version of a bill by a 66 to 11 vote on August 11; and the House acted to accept the Senate bill by a 377 to 10 vote on August 27.

f. August 31, 1962, the bill was signed by the President and became law.

g. October 4, 1962, the President nominated 13 distinguished citizens to be Incorporators, with the statutory responsibility for taking the necessary actions to establish a Communications Satellite Corporation.

The Incorporators, under interim appointments, have held a number of meetings to consider and initiate the steps required to organize the corporation and to apply for a charter under the District of Columbia Business Incorporation Act, as provided under the terms of the Communications Satellite Act.

The Communications Satellite Act of 1962 incorporates the major objectives of the President's policy statement of July 24, 1961. It provides authority for the creation of a private corporation to serve as the United States portion of any global system. It will be privately financed and the essential business management will be in the hands of 12 directors elected by the stockholders and 3 directors appointed by the President and confirmed by the Senate. At the same time that the benefits of profit-making incentives and private management are obtained, the Act is most careful to identify national polciy objectives in relation to the use of commercial communications satellites and to provide the machinery within Government for the regulation of and assistance to the corporation. In such a framework, it is expected that the services the corporation provides and the way it conducts its business will be wholly responsive to the several objectives of the Act.

EXHIBIT 16

Public Law 87-624
87th Congress, H. R. 11040
August 31, 1962

An Act

76 STAT. 419.

To provide for the establishment, ownership, operation, and regulation of a commercial communications satellite system, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—SHORT TITLE, DECLARATION OF POLICY AND DEFINITIONS

SHORT TITLE

SEC. 101. This Act may be cited as the "Communications Satellite Act of 1962".

DECLARATION OF POLICY AND PURPOSE

SEC. 102. (a) The Congress hereby declares that it is the policy of the United States to establish, in conjunction and in cooperation with other countries, as expeditiously as practicable a commercial communications satellite system, as part of an improved global communications network, which will be responsive to public needs and national objectives, which will serve the communication needs of the United States and other countries, and which will contribute to world peace and understanding.

(b) The new and expanded telecommunication services are to be made available as promptly as possible and are to be extended to provide global coverage at the earliest practicable date. In effectuating this program, care and attention will be directed toward providing such services to economically less developed countries and areas as well as those more highly developed, toward efficient and economical use of the electromagnetic frequency spectrum, and toward the reflection of the benefits of this new technology in both quality of services and charges for such services.

(c) In order to facilitate this development and to provide for the widest possible participation by private enterprise, United States participation in the global system shall be in the form of a private corporation, subject to appropriate governmental regulation. It is the intent of Congress that all authorized users shall have nondiscriminatory access to the system; that maximum competition be maintained in the provision of equipment and services utilized by the system; that the corporation created under this Act be so organized and operated as to maintain and strengthen competition in the provision of communications services to the public; and that the activities of the corporation created under this Act and of the persons or companies participating in the ownership of the corporation shall be consistent with the Federal antitrust laws.

(d) It is not the intent of Congress by this Act to preclude the use of the communications satellite system for domestic communication services where consistent with the provisions of this Act nor to preclude the creation of additional communications satellite systems, if required to meet unique governmental needs or if otherwise required in the national interest.

DEFINITIONS

SEC. 103. As used in this Act, and unless the context otherwise requires—

(1) the term "communications satellite system" refers to a system of communications satellites in space whose purpose is to relay telecommunication information between satellite terminal sta-

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EXHIBIT 16 (Cont.)

Pub. Law 87-624
76 STAT. 420.

tions, together with such associated equipment and facilities for tracking, guidance, control, and command functions as are not part of the generalized launching, tracking, control, and command facilities for all space purposes;

(2) the term "satellite terminal station" refers to a complex of communication equipment located on the earth's surface, operationally connected with one or more terrestrial communication systems, and capable of transmitting telecommunications to or receiving telecommunications from a communications satellite system.

(3) the term "communications satellite" means an earth satellite which is intentionally used to relay telecommunication information;

(4) the term "associated equipment and facilities" refers to facilities other than satellite terminal stations and communications satellites, to be constructed and operated for the primary purpose of a communications satellite system, whether for administration and management, for research and development, or for direct support of space operations;

(5) the term "research and development" refers to the conception, design, and first creation of experimental or prototype operational devices for the operation of a communications satellite system, including the assembly of separate components into a working whole, as distinguished from the term "production," which relates to the construction of such devices to fixed specifications compatible with repetitive duplication for operational applications; and

(6) the term "telecommunication" means any transmission, emission or reception of signs, signals, writings, images, and sounds or intelligence of any nature by wire, radio, optical, or other electromagnetic systems.

(7) the term "communications common carrier" has the same meaning as the term "common carrier" has when used in the Communications Act of 1934, as amended, and in addition includes, but only for purposes of sections 303 and 304, any individual, partnership, association, joint-stock company, trust, corporation, or other entity which owns or controls, directly or indirectly, or is under direct or indirect common control with, any such carrier; and the term "authorized carrier", except as otherwise provided for purposes of section 304 by section 304(b)(1), means a communications common carrier which has been authorized by the Federal Communications Commission under the Communications Act of 1934, as amended, to provide services by means of communications satellites;

(8) the term "corporation" means the corporation authorized by title III of this Act.

(9) the term "Administration" means the National Aeronautics and Space Administration; and

(10) the term "Commission" means the Federal Communications Commission.

EXHIBIT 16 (Cont.)

Pub. Law 87-624
76 STAT. 421.

TITLE II—FEDERAL COORDINATION, PLANNING, AND REGULATION

IMPLEMENTATION OF POLICY

SEC. 201. In order to achieve the objectives and to carry out the purposes of this Act—

(a) the President shall—

(1) aid in the planning and development and foster the execution of a national program for the establishment and operation, as expeditiously as possible, of a commercial communications satellite system;

(2) provide for continuous review of all phases of the development and operation of such a system, including the activities of a communications satellite corporation authorized under title ᵀII of this Act;

(3) coordinate the activities of governmental agencies with responsibilities in the field of telecommunication, so as to insure that there is full and effective compliance at all times with the policies set forth in this Act;

(4) exercise such supervision over relationships of the corporation with foreign governments or entities or with international bodies as may be appropriate to assure that such relationships shall be consistent with the national interest and foreign policy of the United States;

(5) insure that timely arrangements are made under which there can be foreign participation in the establishment and use of a communications satellite system;

(6) take all necessary steps to insure the availability and appropriate utilization of the communications satellite system for general governmental purposes except where a separate communications satellite system is required to meet unique governmental needs, or is otherwise required in the national interest; and

(7) so exercise his authority as to help attain coordinated and efficient use of the electromagnetic spectrum and the technical compatibility of the system with existing communications facilities both in the United States and abroad.

(b) the National Aeronautics and Space Administration shall—

(1) advise the Commission on technical characteristics of the communications satellite system;

(2) cooperate with the corporation in research and development to the extent deemed appropriate by the Administration in the public interest;

(3) assist the corporation in the conduct of its research and development program by furnishing to the corporation, when requested, on a reimbursable basis, such satellite launching and associated services as the Administration deems necessary for the most expeditious and economical development of the communications satellite system;

(4) consult with the corporation with respect to the technical characteristics of the communications satellite system;

(5) furnish to the corporation, on request and on a reimbursable basis, satellite launching and associated services required for the establishment, operation, and maintenance of the communications satellite system approved by the Commission; and

EXHIBIT 16 (Cont.)

Pub. Law 87-624
76 STAT. 422.

(6) to the extent feasible, furnish other services, on a reimbursable basis, to the corporation in connection with the establishment and operation of the system.

(c) the Federal Communications Commission, in its administration of the provisions of the Communications Act of 1934, as amended, and as supplemented by this Act, shall—

(1) insure effective competition, including the use of competitive bidding where appropriate, in the procurement by the corporation and communications common carriers of apparatus, equipment, and services required for the establishment and operation of the communications satellite system and satellite terminal stations; and the Commission shall consult with the Small Business Administration and solicit its recommendations on measures and procedures which will insure that small business concerns are given an equitable opportunity to share in the procurement program of the corporation for property and services, including but not limited to research, development, construction, maintenance, and repair.

(2) insure that all present and future authorized carriers shall have nondiscriminatory use of, and equitable access to, the communications satellite system and satellite terminal stations under just and reasonable charges, classifications, practices, regulations, and other terms and conditions and regulate the manner in which available facilities of the system and stations are allocated among such users thereof;

(3) in any case where the Secretary of State, after obtaining the advice of the Administration as to technical feasibility, has advised that commercial communication to a particular foreign point by means of the communications satellite system and satellite terminal stations should be established in the national interest, institute forthwith appropriate proceedings under section 214(d) of the Communications Act of 1934, as amended, to require the establishment of such communication by the corporation and the appropriate common carrier or carriers;

(4) insure that facilities of the communications satellite system and satellite terminal stations are technically compatible and interconnected operationally with each other and with existing communications facilities;

(5) prescribe such accounting regulations and systems and engage in such ratemaking procedures as will insure that any economies made possible by a communications satellite system are appropriately reflected in rates for public communication services;

(6) approve technical characteristics of the operational communications satellite system to be employed by the corporation and of the satellite terminal stations; and

(7) grant appropriate authorizations for the construction and operation of each satellite terminal station, either to the corporation or to one or more authorized carriers or to the corporation and one or more such carriers jointly, as will best serve the public interest, convenience, and necessity. In determining the public interest, convenience, and necessity the Commission shall authorize the construction and operation of such stations by communications common carriers or the corporation, without preference to either;

(8) authorize the corporation to issue any shares of capital stock, except the initial issue of capital stock referred to in section 304(a), or to borrow any moneys, or to assume any

EXHIBIT 16 (Cont.)

obligation in respect of the securities of any other person, upon a finding that such issuance, borrowing, or assumption is compatible with the public interest, convenience, and necessity and is necessary or appropriate for or consistent with carrying out the purposes and objectives of this Act by the corporation;

(9) insure that no substantial additions are made by the corporation or carriers with respect to facilities of the system or satellite terminal stations unless such additions are required by the public interest, convenience, and necessity;

(10) require, in accordance with the procedural requirements of section 214 of the Communications Act of 1934, as amended, that additions be made by the corporation or carriers with respect to facilities of the system or satellite terminal stations where such additions would serve the public interest, convenience, and necessity; and

(11) make rules and regulations to carry out the provisions of this Act.

TITLE III—CREATION OF A COMMUNICATIONS SATELLITE CORPORATION

CREATION OF CORPORATION

SEC. 301. There is hereby authorized to be created a communications satellite corporation for profit which will not be an agency or establishment of the United States Government. The corporation shall be subject to the provisions of this Act and, to the extent consistent with this Act, to the District of Columbia Business Corporation Act. The right to repeal, alter, or amend this Act at any time is expressly reserved.

PROCESS OF ORGANIZATION

SEC. 302. The President of the United States shall appoint incorporators, by and with the advice and consent of the Senate, who shall serve as the initial board of directors until the first annual meeting of stockholders or until their successors are elected and qualified. Such incorporators shall arrange for an initial stock offering and take whatever other actions are necessary to establish the corporation, including the filing of articles of incorporation, as approved by the President.

DIRECTORS AND OFFICERS

SEC. 303. (a) The corporation shall have a board of directors consisting of individuals who are citizens of the United States, of whom one shall be elected annually by the board to serve as chairman. Three members of the board shall be appointed by the President of the United States, by and with the advice and consent of the Senate, effective the date on which the other members are elected, and for terms of three years or until their successors have been appointed and qualified, except that the first three members of the board so appointed shall continue in office for terms of one, two, and three years, respectively, and any member so appointed to fill a vacancy shall be appointed only for the unexpired term of the director whom he succeeds. Six members of the board shall be elected annually by those stockholders who are communications common carriers and six shall be elected annually by the other stockholders of the corporation. No stockholder who is a communications common carrier and no trustee for such a stockholder shall vote, either directly or indirectly, through the votes of subsidiaries or affiliated companies, nominees, or any persons subject to

EXHIBIT 16 (Cont.)

his direction or control, for more than three candidates for membership on the board. Subject to such limitation, the articles of incorporation to be filed by the incorporators designated under section 302 shall provide for cumulative voting under section 27(d) of the District of Columbia Business Corporation Act (D.C. Code, sec. 29–911(d)).

(b) The corporation shall have a president, and such other officers as may be named and appointed by the board, at rates of compensation fixed by the board, and serving at the pleasure of the board. No individual other than a citizen of the United States may be an officer of the corporation. No officer of the corporation shall receive any salary from any source other than the corporation during the period of his employment by the corporation.

FINANCING OF THE CORPORATION

SEC. 304. (a) The corporation is authorized to issue and have outstanding, in such amounts as it shall determine, shares of capital stock, without par value, which shall carry voting rights and be eligible for dividends. The shares of such stock initially offered shall be sold at a price not in excess of $100 for each share and in a manner to encourage the widest distribution to the American public. Subject to the provisions of subsections (b) and (d) of this section, shares of stock offered under this subsection may be issued to and held by any person.

(b)(1) For the purposes of this section the term "authorized carrier" shall mean a communications common carrier which is specifically authorized or which is a member of a class of carriers authorized by the Commission to own shares of stock in the corporation upon a finding that such ownership will be consistent with the public interest, convenience, and necessity.

(2) Only those communications common carriers which are authorized carriers shall own shares of stock in the corporation at any time, and no other communications common carrier shall own shares either directly or indirectly through subsidiaries or affiliated companies, nominees, or any persons subject to its direction or control. Fifty per centum of the shares of stock authorized for issuance at any time by the corporation shall be reserved for purchase by authorized carriers and such carriers shall in the aggregate be entitled to make purchases of the reserved shares in a total number not exceeding the total number of the nonreserved shares of any issue purchased by other persons. At no time after the initial issue is completed shall the aggregate of the shares of voting stock of the corporation owned by authorized carriers directly or indirectly through subsidiaries or affiliated companies, nominees, or any persons subject to their direction or control exceed 50 per centum of such shares issued and outstanding.

(3) At no time shall any stockholder who is not an authorized carrier, or any syndicate or affiliated group of such stockholders, own more than 10 per centum of the shares of voting stock of the corporation issued and outstanding.

(c) The corporation is authorized to issue, in addition to the stock authorized by subsection (a) of this section, nonvoting securities, bonds, debentures, and other certificates of indebtedness as it may determine. Such nonvoting securities, bonds, debentures, or other certificates of indebtedness of the corporation as a communications common carrier may own shall be eligible for inclusion in the rate base of the carrier to the extent allowed by the Commission. The vot-

EXHIBIT 16 (Cont.)

ing stock of the corporation shall not be eligible for inclusion in the rate base of the carrier.

(d) Not more than an aggregate of 20 per centum of the shares of stock of the corporation authorized by subsection (a) of this section which are held by holders other than authorized carriers may be held by persons of the classes described in paragraphs (1), (2), (3), (4), and (5) of section 310(a) of the Communications Act of 1934, as amended (47 U.S.C. 310).

(e) The requirement of section 45(b) of the District of Columbia Business Corporation Act (D.C. Code, sec. 29-920(b)) as to the percentage of stock which a stockholder must hold in order to have the rights of inspection and copying set forth in that subsection shall not be applicable in the case of holders of the stock of the corporation, and they may exercise such rights without regard to the percentage of stock they hold.

(f) Upon application to the Commission by any authorized carrier and after notice and hearing, the Commission may compel any other authorized carrier which owns shares of stock in the corporation to transfer to the applicant, for a fair and reasonable consideration, a number of such shares as the Commission determines will advance the public interest and the purposes of this Act. In its determination with respect to ownership of shares of stock in the corporation, the Commission, whenever consistent with the public interest, shall promote the widest possible distribution of stock among the authorized carriers.

PURPOSES AND POWERS OF THE CORPORATION

SEC. 305. (a) In order to achieve the objectives and to carry out the purposes of this Act, the corporation is authorized to—

(1) plan, initiate, construct, own, manage, and operate itself or in conjunction with foreign governments or business entities a commercial communications satellite system;

(2) furnish, for hire, channels of communication to United States communications common carriers and to other authorized entities, foreign and domestic; and

(3) own and operate satellite terminal stations when licensed by the Commission under section 201(c)(7).

(b) Included in the activities authorized to the corporation for accomplishment of the purposes indicated in subsection (a) of this section, are, among others not specifically named—

(1) to conduct or contract for research and development related to its mission;

(2) to acquire the physical facilities, equipment and devices necessary to its operations, including communications satellites and associated equipment and facilities, whether by construction, purchase, or gift;

(3) to purchase satellite launching and related services from the United States Government;

(4) to contract with authorized users, including the United States Government, for the services of the communications satellite system; and

(5) to develop plans for the technical specifications of all elements of the communications satellite system.

(c) To carry out the foregoing purposes, the corporation shall have the usual powers conferred upon a stock corporation by the District of Columbia Business Corporation Act.

EXHIBIT 16 (Cont.)

Pub. Law 87-624
76 STAT. 426.

TTLE IV—MISCELLANEOUS

APPLICABILITY OF COMMUNICATIONS ACT OF 1934

SEC. 401. The corporation shall be deemed to be a common carrier within the meaning of section 3(h) of the Communications Act of 1934, as amended, and as such shall be fully subject to the provisions of title II and title III of that Act. The provision of satellite terminal station facilities by one communication common carrier to one or more other communications common carriers shall be deemed to be a common carrier activity fully subject to the Communications Act. Whenever the application of the provisions of this Act shall be inconsistent with the application of the provisions of the Communications Act, the provisions of this Act shall govern.

NOTICE OF FOREIGN BUSINESS NEGOTIATIONS

SEC. 402. Whenever the corporation shall enter into business negotiations with respect to facilities, operations, or services authorized by this Act with any international or foreign entity, it shall notify the Department of State of the negotiations, and the Department of State shall advise the corporation of relevant foreign policy considerations. Throughout such negotiations the corporation shall keep the Department of State informed with respect to such considerations. The corporation may request the Department of State to assist in the negotiations, and that Department shall render such assistance as may be appropriate.

SANCTIONS

SEC. 403. (a) If the corporation created pursuant to this Act shall engage in or adhere to any action, practices, or policies inconsistent with the policy and purposes declared in section 102 of this Act, or if the corporation or any other person shall violate any provision of this Act, or shall obstruct or interfere with any activities authorized by this Act, or shall refuse, fail, or neglect to discharge his duties and responsibilities under this Act, or shall threaten any such violation, obstruction, interference, refusal, failure, or neglect, the district court of the United States for any district in which such corporation or other person resides or may be found shall have jurisdiction, except as otherwise prohibited by law, upon petition of the Attorney General of the United States, to grant such equitable relief as may be necessary or appropriate to prevent or terminate such conduct or threat.

(b) Nothing contained in this section shall be construed as relieving any person of any punishment, liability, or sanction which may be imposed otherwise than under this Act.

(c) It shall be the duty of the corporation and all communications common carriers to comply, insofar as applicable, with all provisions of this Act and all rules and regulations promulgated thereunder.

REPORTS TO THE CONGRESS

SEC. 404. (a) The President shall transmit to the Congress in January of each year a report which shall include a comprehensive description of the activities and accomplishments during the preceding calendar year under the national program referred to in section 201(a)(1), together with an evaluation of such activities and accomplishments in terms of the attainment of the objectives of this Act and any recommendations for additional legislative or other action which the President may consider necessary or desirable for the attainment of such objectives.

EXHIBIT 16 (Cont.)

(b) The corporation shall transmit to the President and the Congress, annually and at such other times as it deems desirable, a comprehensive and detailed report of its operations, activities, and accomplishments under this Act.

(c) The Commission shall transmit to the Congress, annually and at such other times as it deems desirable, (i) a report of its activities and actions on anticompetitive practices as they apply to the communications satellite programs; (ii) an evaluation of such activities and actions taken by it within the scope of its authority with a view to recommending such additional legislation which the Commission may consider necessary in the public interest; and (iii) an evaluation of the capital structure of the corporation so as to assure the Congress that such structure is consistent with the most efficient and economical operation of the corporation.

Approved August 31, 1962, 9:51 a.m.

Appendix E

SELECTED HISTORICAL PUBLICATIONS AND REPORTS*

BOOKS

"Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Space, 1915–1960," with a Foreword by Dr. Hugh L. Dryden. Washington: U.S. Government Printing Office, 1961, $1.75.

"Aeronautical and Astronautical Events of 1961," with a Foreword by James E. Webb, published by the House Committee on Science and Astronautics, June 7, 1962.

"Astronautical and Aeronautical Events of 1962," with a Foreword by Dr. George L. Simpson, Jr., published by the House Committee on Science and Astronautics, June 12, 1963. Offered for sale by the Supt. of Documents ($1.00). Washington: U.S. Government Printing Office, $1.00.

"History of Rocket Technology," special issue of *Technology and Culture* edited by the NASA Historian, Fall 1963, containing essays by G. Edward Pendray, Walter R. Dornberger, John P. Hagen, Wernher von Braun, and others.

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HHR–2—"Robert H. Goddard: American Rocket Pioneer," (July 1960), reprinted as "Yesterday's Dream . . . Today's Reality," *Airpower Historian* (October 1960)—H. Emme.

HHR–6—"Historical Origins of NASA," (Comment Edition issued November 1961), revised June 1962—E. Emme.

HHR–8—"Chronology of Major NASA Launchings, 1958–62," R. Rosholt.

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*As of December 1962.

Appendix F

GODDARD SPACE FLIGHT CENTER TECHNICAL NOTES AND TECHNICAL REPORTS

TECHNICAL NOTES*

D–355—"Some Basic Considerations of Telemetry System Design," by H. J. Peake, June 1960

D–356—"Interim Definitive Orbit for the Satellite 1958-Gamma, Explorer III," by Theory and Analysis Staff, June 1960

D–357—"Determination of the Internal Temperature in Satellite 1959 Alpha (Vanguard II)," by V. R. Simas, J. B. Martin, and E. C. Humphrey, June 1960

D–358—"The Vector Field Proton Magnetometer for IGY Satellite Ground Stations," by I. R. Shapiro, J. D. Stolarik, and J. P. Heppner, October 1960

D–359—"Interim Definitive Orbit for the Satellite 1958-Alpha, Explorer I," by Theory and Analysis Staff, September 1960

D–410—"Interim Definitive Orbit for the Satellite 1958-Epsilon, Explorer IV," by Theory and Analysis Staff, September 1960

D–411—"Interim Definitive Orbit for the Satellite 1959 Alpha Vanguard-II," by Theory and Analysis Staff, September 1960

D–412—"The Flux and Energy Spectra of the Protons in the Inner Van Allen Belt," by J. E. Naugle and D. A. Kniffen, August 1961

D–413—"Rocket Measurement of a Daytime Electron Density Profile up to 620 Kilometers," by J. E. Jackson and S. J. Bauer, September 1961

D–414—"Instrumentation of the Ionosphere Direct Measurements Satellite (Explorer (VIII)," by R. E. Bourdeau, J. L. Donley, and E. C. Whipple, Jr., April 1962

D–485—"A Low-Resolution Unchopped Radiometer for Satellites," by R. A. Hanel, February 1961

D–486—"Project Vanguard Magnetic-Field Instrumentation and Measurements," by J. P. Heppner, J. D. Stolarik, I. R. Shapiro, and J. C. Cain, September 1960

D–487—"The Solar Wind," by J. R. Herring and A. L. Licht, September 1960

D–488—"Recent Direct Measurements by Satellites of Cosmic Dust in the Vicinity of the Earth," by H. E. LaGow and W. M. Alexander, September 1960

D–489—"Determination of Satellite Orbits from Radar Data," by W. F. Cahill and I. Harris, September 1960

D–490—"The Origin of Tektites," by J. A. O'Keefe, November 1960

D–491—"Ionospheric Measurements Using Environmental Sampling Techniques," by R. E. Bourdeau, J. E. Jackson, J. A. Kane, and G. P. Serbu, September 1960

D–492—"A Modified Hansen's Theory As Applied to the Motion of Artificial Satellites," by P. Musen, November 1960

D–493—"A Method of Estimating Residuals in Orbital Theory," by M. Lecar, January 1961

D–494—"Development of the Lunar and Solar Pertubations in the Motion of an Artificial Satellite," by P. Musen, A. E. Bailie, and E. Upton, January 1961

D–495—"Vanguard I Satellite Structure and Separation Mechanism," by J. T. Shea and R. C. Baumann, March 1961

D–496—"Vanguard Satellite Spin-Reduction Mechanism," by R. C. Baumann, April 1961

D–497—"Vanguard Satellite Separation Mechanisms," by R. C. Baumann, April 1961

D–498—"Balancing Vanguard Satellites," by A. Simkovich and R. C. Baumann, April 1961

D–499—"The Limiting Sizes of the Habitable Planets," by Su-Shu Huang, September 1960

*As of December 1962.

D–500—"The Dielectric Bolometer, A New Type of Thermal Radiation Detector," by R. A. Hanel, November 1960

D–501—"Very Restricted Four-Body Problem," by Su-Shu Huang, September 1960

D–502—"Some Dynamical Properties of the Natural and Artificial Satellites," by Su-Shu Huang, September 1960

D–503—"Reevaluation of Ionospheric Electron Densities and Collision Frequencies Derived from Rocket Measurements of Refractive Index and Attenuation," by J. A. Kane, November 1960

D–504—"A Thermistor Pressure Gauge," by A. P. Flanick and J. Ainsworth, November 1960

D–565—"The Javelin Spike Antenna; Radiation Patterns and Voltage Standing-Wave Ratio," by R. R. Ford, January 1961

D–566—"Rotational Magnetodynamics and Steering of Space Vehicles," by R. H. Wilson, Jr., September 1961

D–567—"Direct Measurements of Ion Density and Conductivity in the D-Region," by E. C. Whipple, Jr., October 1960

D–568—"Osculating Elements Derived from the Modified Hansen's Theory for the Motion of an Artificial Satellite," by A. E. Bailie and R. Bryant, January 1961

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D–570—"Results from a Rocket-Borne Langmuir Probe Experiment," by G. P. Serbu, July 1961

D–571—"Angular Motion of the Spin Axis of the Tiros I Meteorological Satellite Due to Magnetic and Gravitational Torques," by W. R. Bandeen and W. P. Manger, April 1961

D–572—"Analysis of Gravitational and Geometric Aspects of Geodetic Utilization of Satellites," by W. M. Kaula, March 1961

D–573—"On the Accuracy of an Elliptical Orbit Determination," by R. F. Weirauch, January 1961

D–665—"The Ion-Trap Results in 'Exploration of the Upper Atmosphere with the Help of the Third Soviet Sputnik,'" by E. C. Whipple, Jr., January 1961

D–666—"Eight-Level Pulse-Height Analyzer for Space Physics Applications," by U. D. Desai, R. L. VanAllen, and G. Porreca, January 1961

D–667—"Summary of Rocket and Satellite Observations Related to the Ionosphere," by J. C. Seddon, January 1961

D–668—"Polyester Film Belts," by J. H. Licht and A. White, May 1961

D–669—"A Very Low Frequency (VLF) Synchronizing System," by C. H. Looney, Jr., February 1961

D–670—"Measurement of Upper-Atmosphere Structure by Means of the Pitot-Static Tube," by J. E. Ainsworth, D. F. Fox, and H. E. LaGow, February 1961

D–671—"Discussions of Solar Proton Events and Manned Space Flight," by K. A. Anderson and C. E. Fichtel, March 1961

D–672—"A Digital Recording System for Satellite Tracking Data," by T. P. Sifferlen and W. M. Hocking, March 1961

D–673—"Ultraviolet Astronomical Photometry From Rockets," by A. Boggess, III, June 1962

D–674—"An Instrument To Measure the Solar Constant From a Satellite," by R. A. Hanel, April 1961

D–696—"Satellite Magnetic Field Mapping," by J. P. Heppner, J. C. Cain, I. R. Shapiro, and J. D. Stolarik, May 1961

D–697—"Broad-Band Ultraviolet Filters," by C. B. Childs, April 1961

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D–700—"Preliminary Study of Prediction Aspects of Solar Cosmic Ray Events," by K. A. Anderson, April 1961

D–701—"Physical Significance of the Tiros II Radiation Experiment," by R. A. Hanel and D. Q. Wark, December 1961

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D–1062—"A Digital Solar Aspect Sensor," by J. S. Albus, September 1961

D–1063—"The Effect of Solar Radiation Pressure on the Motion of an Artificial Satellite," by R. W. Bryant, September 1961

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D–1076—"A Digital Command System for Satellites," by F. A. Kierner, Jr., February 1962

D–1077—"Initial Investigation of Monopole Antenna Systems for Use on Spherical Metal Satellites, by R. R. Ford and L. F. Schmadebeck, February 1962

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D–1121—"Sun Tracking by the Minitrack Tracking Stations," by E. J. Habib, J. H. Berbert, and D. W. Harris, March 1962

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D–1126—"A Development of the Lunar And Solar Disturbing Functions for a Close Satellite," by W. M. Kaula, January 1962

D–1127—"Participation of Bell Telephone Laboratories in Project Echo and Experimental Results," by W. C. Jakes, Jr., December 1961

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D–1129—"Project Echo—960-Megacycle, 10-Kilowatt Transmitter," by J. P. Schafer and R. H. Brandt, October 1961

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D–1137—"Project Echo—Antenna Steering System," by R. Klahn, J. A. Norton, and J. A. Githens, September 1961

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D–1139—"Solar Protons," by K. W. Ogilvie, July 1962

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D–1177—"Computational Procedure for Vinti's Theory of an Accurate Intermediary Orbit," by N. L. Bonavito, March 1962

D–1178—"Analysis of the 'Range and Range Rate' Tracking System," by F. O. Vonbun, January 1962

D–1179—"Long Period Effects of the Ellipticity of the Earth's Equator on the Motion of Artificial Satellites," by P. Musen, May 1962

D–1180—"Ceramic Vacuum Ultraviolet Ion Chambers," by A. K. Stober, March 1962

D–1290—"An Addition to the Yale Tables for the Development of the Disturbing Function," by L. Carpenter, March 1962

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D–1292—"A Pulsed Frequency Modulation Decommutator," by H. H. Levy, A. M. Demmerle, and J. L. Tinsley, June 1962

D–1293—"Telemetering Infrared Data from the Tiros Meteorological Satellites," by J. F. Davis, R. A. Hanel, R. A. Stampfl, M. G. Strange, and M. R. Townsend, August 1962

D–1294—"Acoustic Phenomena Observed on Rocket-Borne High Altitude Explosions," by W. Nordberg, June 1962

D–1336—"The Earth's Free Oscillations," by G. J. F. MacDonald, June 1962

D–1337—"A Tunnel-Diode Counter for Satellite Applications," by E. G. Bush, June 1962

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D–1340—"Scientific Satellites and the Space Environment," by J. C. New, June 1962

D–1341—"Earth Scan Analog Signal Relationships in the Tiros Radiation Experiment and Their Application to the Problem of Horizon Sensing," by B. J. Conrath, June 1962

D–1342—"The Composition of Gases in a Tektite Bubble," by J. A. O'Keefe, K. L. Dunning, and R. D. Lowman, Jr., July 1962

D–1343—"Nonadiabatic Theory of Electron–Hydrogen Scattering," by A. Temkin, July 1962

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D–1346—"Experimental Evidence for the Presence of Helium Ions in the Upper Atmosphere Based on Explorer VIII Satellite Data," by R. E. Boudeau, E. C. Whipple, Jr., J. L. Donley, and S. J. Bauer, July 1962

D–1347—"Calculation of the Eclipse Factor for Elliptical Satellite Orbits," by F. G. Cunningham, June 1962

D–1348—"Spacecraft Information Systems," by G. H. Ludwig, October 1962

D–1349—"The Distribution of Small Interplanetary Dust Particles in the Vicinity of the Earth," by C. W. McCracken and W. M. Alexander, July 1962

D–1350—"Computation of the Perturbations of Nearly Circular Orbits, Using a Non-Singular Set of Vectorial Elements," by P. Musen, August 1962

D–1413—"A Preliminary Study of the Orbits of Merit for Moon Probes," by Su-Shu Huang, July 1962

D–1414—"A Stellar Model of Mixed Opacity and its Variations with the Mass, Chemical Composition, Opacity Coefficients, and Energy-Generation Coefficient," by Su-Shu Huang, July 1962.

D–1415—"Calculation of Ephemerides from Initial Values," by K. Stumpff, December 1962

D–1418—"Measurements of the Geomagnetic Field by the Vanguard III Satellite," by J. C. Cain, I. R. Shapiro, J. D. Stolarik, and J. P. Heppner, October 1962

D–1419—"A Phase-Locked Phase Filter for the Minitrack System," by R. F. Woodman, September 1962

D–1420—"A Method of Accurately Reducing the Spin Rate of a Rotating Spacecraft," by H. J. Cornille, Jr., October 1962.

D–1421—"Pulse Frequency Modulation," by R. W. Rochelle, October 1962

D–1443—"Time-Dependent Structure of the Upper Atmosphere," by I. Harris and W. Priester, July 1962

D–1444—"Theoretical Models for the Solar-Cycle Variation of the Upper Atmosphere, by I. Harris and W. Priester, August 1962

D–1445—"Differential Correction for Vinti's Accurate Intermediary Orbit," by N. L. Bonavito, December 1962

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D–1447—"The Magnetic Field of a Model Radiation Belt Numerically Computed," by Syun-Ichi Akasofu, J. C. Cain, and S. Chapman, November 1962

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D–1463—"Radiometric Measurements from Satellites," by R. A. Hanel, October 1962

D–1464—"A Double Gamma-Ray Spectrometer To Search for Positrons in Space," by T. L. Cline, P. Serlemitsos, and E. W. Hones, Jr., October 1962

D–1465—"The Early Chronology of the Solar System," by A. G. W. Cameron, August 1962

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D–1467—"On Scaling Laws for Material Damping," by S. H. Crandall, December 1962

D–1469—"Rotational Decay of the Satellite 1960 Eta 2 Due to the Earth's Magnetic Field," by R. H. Wilson, Jr., October 1962

D–1470—"Satellite Motion in the Vicinity of Critical Inclination," by D. Fisher, October 1962

D–1471—"Tracking Systems, Their Mathematical Models and Their Errors. Part 1—Theory," by F. O. Vonbun and W. D. Kahn, October 1962

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R–136—"A Study of the Free Oscillations of the Earth," by G. J. F. MacDonald and N. F. Ness, 1962

R–141—"On the Heating of the Polar Upper Atmosphere," by K. Maeda, 1962

R–144—"The Evolution of Massive Stars, Part III. Hydrogen Exhaustion Through the Onset of Carbon Burning," by C. Hayashi and R. C. Cameron, 1962

R–147—"Computation of Satellite Orbits by the Hansen Method As Modified by Musen," by H. T. Phelan, 1962

Appendix G

BIBLIOGRAPHY BEARING ON GODDARD SPACE FLIGHT CENTER PROGRAMS

INTRODUCTION

This is a list of selected publications and releases of the National Aeronautics and Space Administration issued during the three years following the Agency's establishment in October 1958. Section I contains NASA Technical Notes, Technical Reports, and Technical Translations, and other technical articles having NASA sponsorship. Section II contains selected NASA releases, speeches, and general information and educational publications. Section III contains Congressional documents relating to NASA activities.

AVAILABILITY OF PUBLICATIONS LISTED

SECTION I

NASA Technical Notes and Technical Translations may be purchased from the Office of Technical Services (OTS), U.S. Department of Commerce, Washington, D.C., 20235. NASA Technical Reports may be purchased from the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, D.C., 20402. Other documents, except articles published in technical journals, may be obtained from the National Aeronautics and Space Administration, Office of Scientific and Technical Information, Code AFSS–AD, Washington, D.C., 20546, or from the organization listed.

Organizations requiring items for government-sponsored programs may obtain copies, within the limitation of the supply available, from the NASA Office of Scientific and Technical Information.

SECTION II

The speeches and releases listed are available from NASA, Office of Scientific and Technical Information, Code AFSS–AD, Washington, D.C., 20546. The informational and educational publications listed are available from NASA, Office of Educational Programs and Services, Code AFE, Washington, D.C., 20546.

SECTION III

Congressional documents listed may be purchased from the Photoduplication Service, Library of Congress, Washington, D.C., 20540. Those marked with an asterisk are also available at the many libraries in the United States that are utilized by the U.S. Government Printing Office as depository libraries. Those documents listed with a GPO price are currently available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

Section I

NASA TECHNICAL PUBLICATIONS

SPACECRAFT

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Section II

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